U. S. DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES

PROGRESS IN BIOLOGICAL INQUIRIES 1934

By ELMER HIGGINS

ADMINISTRATIVE REPORT No. 21

U. S. DEPARTMENT OF COMMERCE
DANIEL C. ROPER, Secretary
BUREAU OF FISHERIES
FRANK T. BELL, Commissioner

Administrative Report No. 21

PROGRESS IN BIOLOGICAL INQUIRIES 1934

By ELMER HIGGINS

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FOR THE FISCAL YEAR 1935

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ADMINISTRATIVE REPORT SERIES

Since the advent of the Administrative Report Series, considerable confusion has arisen concerning its system of numbering the separates composing it. Inasmuch as the Reports of the Divisions vary in order from year to year, many have found their designations, as "Appendix No. I, II, III, or IV", is very confusing. To relieve this, it has been decided to number them as "Administrative Report No. —." Inasmuch as 20 separates have already been printed in this series, it is deemed advisable to begin the numbering with Administrative Report No. 21. Of course, numbers cannot be printed on those already off the press, but for the information of those who wish to know what the first 20 were, they are numbered for filing purposes as follows:

No. 1. Report, Commissioner of Fisheries, 1931.
No. 2. Alaska Fishery and Fur-Seal Industries, 1930.
No. 3. Fishery Industries of the United States, 1930.
No. 4. Progress in Biological Inquiries, 1930.
No. 5. Propagation and Distribution of Food Fishes, 1931.
No. 6. Report Commissioner of Fisheries, 1932.
No. 7. Alaska Fishery and Fur-Seal Industries, 1931.
No. 8. Fishery Industries of the United States, 1931.
No. 9. Progress in Biological Inquiries, 1931.
No. 10. Propagation and Distribution of Food Fishes, 1932.
No. 11. Alaska Fishery and Fur-Seal Industries, 1932.
No. 12. Progress in Biological Inquiries, 1932.
No. 13. Fishery Industries of the United States, 1932.
No. 14. Propagation and Distribution of Food Fishes, 1933.
No. 15. Fishery Industries of the United States, 1933.
No. 16. Alaska Fishery and Fur-Seal Industries, 1933.
No. 17. Progress in Biological Inquiries, 1933.
No. 18. Propagation and Distribution of Food Fishes, 1934.
No. 19. Alaska Fishery and Fur-Seal Industries, 1934.
No. 20. Fishery Industries of the United States, 1934.

Note that the last Commissioner's Report was for 1932. Since then its place has been taken by a reprint from the Report of the Secretary of Commerce under the title "Bureau of Fisheries." Inasmuch as it is no longer a Bureau publication, it is not numbered; but it will be supplied to any who request the Report of the Commissioner for any year since 1932.

PROGRESS IN BIOLOGICAL INQUIRIES, 1934[1]

By Elmer Higgins, *Chief, Division of Scientific Inquiry*

[With the collaboration of investigators]

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[1]Administrative Report No. 21, Appendix III to the Report of the U. S. Commissioner of Fisheries for 1935. Approved for publication, Nov. 7, 1935.

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INTRODUCTION

The United States Bureau of Fisheries is the only Federal agency conducting research looking toward the development and conservation of the fishery resources in the United States. The major portion of research on conservation problems is conducted by the Division of Scientific Inquiry, for technological research is mainly promotive and contributes only indirectly to a solution of the problems of conservation by promoting a fuller use of fishery products. As a general rule, the State governments do not have facilities nor resources for the conduct of fishery research on an extensive scale. Many States, however, contribute to or cooperate effectively in work conducted by the United States Bureau of Fisheries.

The technical staff of the Division of Scientific Inquiry numbers 45 trained experts, with perhaps an equal number of temporary assistants at some time of the year, but the problems of the fisheries are as numerous as the species that are exploited. Some 30 important food and game fishes are the subjects of continuing research. To give adequate attention to the fisheries in all sections of the United States, both coastal and interior, and in Alaska, at least double this number of investigators would be required.

The aim of fishery investigations is to determine which species are showing depletion as a result of man's exploitation, what methods may be applied toward their conservation through the management of supplies on the basis of sustained yield, and the development of improved methods of cultivating aquatic animals. From a scientific standpoint research is conducted in the various fields of applied sciences, including fishery biology and aquiculture, and in the fundamental sciences of ecology, oceanography, limnology, physiology, systematic ichthyology, and biostatistics. Research projects during the past year were organized under three major branches: (1) Commercial fishery investigations in marine and fresh waters; (2) aquicultural investigations, including improvements in the propagation of fresh-water fish and the study of aquatic environments and pollution control; and (3) shellfishery investigations for the development of oyster farming and the control of shellfish pests. These projects are organized under seven distinct sections, each directed

by a responsible and experienced fishery biologist, and are so distributed as to cover each of the major geographical sections of the United States.

The problems of the fresh-water fisheries throughout the country at the present time are concerned chiefly with increasing hatchery output and stocking interior waters. The chief hatchery problems concerning output are proper diet and the control of disease. Through 10 years of research the Division has found cures for several bacterial diseases of hatchery fish, and has improved diets until 1 pound of trout can be produced from 3 pounds of food, with an increase in efficiency in feeding of about one-third.

The most outstanding problems in the stocking of interior waters are concerned with the development of a stocking policy. More attention must be given to placing the fish in suitable waters which contain an adequate natural food supply, and to producing larger fish better able to survive than heretofore in order to provide better angling. In this field the Bureau is cooperating with the United States Forest Service in devising better management of fishery resources comparable with the improved game-management program.

One of the most serious limitations on the maintenance of abundant stocks of food and game fishes in interior waters and the chief hindrance in stocking these waters with additional supplies is pollution from domestic and industrial sources. The destruction of fish life by polluting substances, already acute in many localities, is growing rapidly throughout the more densely settled and industrialized sections of the country. A temporary staff, working on emergency funds, has made great progress during the past year in determining the effect of stream pollution on aquatic life. The classification of polluting substances according to their biological effects and the determination of their potencies will permit the formulation of standards of water purity favorable to the production of an abundant fish supply and form the basis of an effective policy of stream purification and protection.

The second major activity of the Division is concerned with investigations of the commercial fisheries. During the past 10 years progress has been made in determining the causes of great changes in abundance of commercial fishes. During the period continued observation of the trend and condition of the fisheries has revealed dangers of depletion and abuses in commercial practice that menace the supply. It remains, however, to educate the public regarding conservation measures to be followed voluntarily by the trade or to be enforced by legislation. It also remains to keep continual check by scientific means from year to year on the changing supply and the effects of regulation.

One of the most significant and promising new undertakings of the Division during the past year is the inauguration of a comprehensive study of the fisheries of the Columbia River Basin. Attacking the problem of the fisheries of the basin as a whole, attention is being given to such matters as regulation of the commercial fishing in the lower estuary of the Columbia, which is believed to be depleting the stock; the protection of upstream migrants from loss at power dams; the reclamation or improvement of spawning areas to increase natural reproduction; improvement in the technique of artificial propa-

gation, where such is necessary to supplement natural propagation; the protection of downstream migrants from loss in irrigation works and at power dams; and the prevention of stream pollution. A competent staff has made a satisfactory beginning in this great undertaking, and if the management of the resource is based upon continued scientific studies we may be assured of its permanent productiveness.

The third branch of activity of the Division is concerned with the shellfish industry. Oysters are the most valuable single marine product and are the most susceptible to cultivation and management. The Bureau has assisted in continuing improvements in oyster farming, but there remains a vast field for service in directing oyster planting as a means of public relief and as conservation of the resources. Technical control and experiment are still required.

COOPERATIVE INVESTIGATIONS

For many years the Bureau has had valuable informal cooperation in fishery investigations from many institutions, both public and private, but the acceptance of formal cooperation was not legally authorized until the passage of an act of Congress approved May 21, 1930. The Bureau's program has always been closely correlated with work of various bureaus of the Department of Commerce from which it secures assistance of various kinds, chiefly relating to the promotive aspects of commercial fishery investigations. During the past year closer cooperation has been established with the United States Forest Service and the Bureau of Biological Survey of the Department of Agriculture, in relation to the development of fisheries of interior waters.

Reference has been made to fishery investigations conducted by the States. California has continued with the Bureau its cooperative investigations concerned with the trout supply, looking toward securing a more adequate supply of fish in streams and the more rational regulation of fishing within its borders. New York State has continued its cooperation in the conduct of studies of the nutritional requirements of trout to improve hatchery practices in feeding and rearing. Oregon has cooperated with a Bureau investigator in a study of fish diseases and hatchery practices. North Carolina, Connecticut, and Washington have assisted in investigations for the restoration of oyster beds in their coastal waters, and Georgia, Louisiana, and Texas have taken an active part in the study of the important shrimp fisheries investigations of the South Atlantic and Gulf coast. Despite the fact that State budgets have been reduced proportional to Federal budgets for these projects, this cooperation has been very effective and is greatly appreciated.

Another source of most valuable cooperation is provided by educational institutions, chiefly universities. Laboratory quarters for the Bureau's investigative staffs are provided by Harvard University as headquarters for North and Middle Atlantic fishery investigations, the University of Michigan as headquarters for the Great Lakes fishery investigations, the University of Utah for fishery investigations in the intermountain section, University of Missouri for investigation of interior waters, and Stanford University for California

trout investigations. The Wisconsin Natural History and Geologic Survey has cooperated with the Bureau in many ways. Yale University, Cornell University, the University of Washington, and the Oregon State Agricultural College have likewise provided quarters or other facilities for investigative work.

The value of this type of cooperation cannot be overestimated. The Bureau's investigators receive, in addition to actual laboratory and office quarters, the use of university libraries, advice, and assistance from the university faculties, and many other courtesies which stimulate a community of interest in technical problems of the fisheries. The universities thus contribute to research of practical value and application to their own communities; and their graduate students receive stimulation and advice in research problems similar to those of the Bureau and frequently part-time or temporary employment in Bureau projects, all of which contributes to the progress of aquatic biology in the United States.

Grateful acknowledgment of these various forms of cooperation is made as a rule in the section dealing with fishery investigations in the various localities.

PUBLICATIONS

Owing to the curtailed funds for printing the number of publications resulting from investigations of the staff or conducted under the supervision of the Division has been reduced. The list of papers published by the Bureau during 1934 follows:

DAVIDSON, FREDERICK A.
The homing instinct and age at maturity of pink salmon (*Oncorhynchus gorbuscha*). Bulletin No. 15, 13 pp., 10 figs.

DAVIS, H. S.
Care and diseases of trout. Investigational Report No. 22, 69 pp., 15 figs.

HIGGINS, ELMER.
Progress in biological inquiries, 1933. Appendix III, Report, Commissioner of Fisheries, 1934, pp. 313–383.

HILDEBRAND, SAMUEL F., and LOUELLA CABLE.
Reproduction and development of whitings or kingfishes, drums, spot, croaker, and weakfishes or sea trouts, family Sciaenidae, of the Atlantic coast of the United States. Bulletin No. 16, 57 pp., 44 figs.

SETTE, O. E.
Outlook for the mackerel fishery, 1934. Fishery Circular No. 17, 6 pp., 1 fig.

SETTE, O. E., and A. W. H. NEEDLER.
Statistics of the mackerel fishery off the east coast of North America, 1804 to 1930. Investigational Report No. 19, 48 pp., 6 figs.

The following papers were published by members of the staff of the Division of Scientific Inquiry or cooperating investigators during the year 1934 outside of the Bureau of Fisheries' series:

DAVIS, H. S.
The purpose and value of stream improvement. Transactions, American Fisheries Society, vol. 64, pp. 63–67.
Growth and heredity in trout. Transactions, American Fisheries Society, vol. 64, pp. 197–201.

DEASON, HILARY J.
Preliminary report on the growth rate, dominance, and maturity of the pike-perches (*Stizostedion*) of Lake Erie. Transactions, American Fisheries Society, vol. 63, pp. 348–360.
The development of fishes. The Fisherman, vol. 3, no. 11, pp. 1, 3, November.

FIRTH, FRANK E.
Anthias nicholsi, a new fish taken off Virginia in the deep water trawl fishery. Copeia, no. 4, 1933 (1934).
Scyliorhinus retifer embryo in capsule. Copeia, no. 1, 1934.
FISH, FREDERIC F.
Ulcer disease of trout. Transactions, American Fisheries Society, vol. 64, pp. 252–258.
GALTSOFF, PAUL S.
The biochemistry of the invertebrates of the sea. Ecological Monographs, vol. 4, 1934, pp. 481–490.
Factors governing the propagation of oysters and other marine invertebrates. Proceedings of Fifth Science Congress, pp. 4119–4120.
The mystery of the ocean. Scientific Monthly, August 1934, pp. 172–175.
The use of slag in oyster culture. Fishing Magazine, March 1934, pp. 11–12.
HAZZARD, A. S.
Low water temperature, a limiting factor in the successful production of trout in natural waters. Transactions, American Fisheries, Society, vol. 63.
Limnological studies of the Strawberry Reservoir, Utah. [Abstract.] Proceedings Utah Academy of Sciences, Arts and Letters, vol. XI.
The Rocky Mountain whitefish. The Rocky Mountain Sportsman, January.
The rainbow and the steelhead. The Rocky Mountain Sportsman, March.
Improving our fishing waters. The Rocky Mountain Sportsman, April.
Progress of stream improvement in Utah. The Rocky Mountain Sportsman, November.
HAZZARD, A. S., and M. J. MADSEN.
Studies of the food of the cutthroat trout. Transactions, American Fisheries Society, vol. 63.
HIGGINS, ELMER.
A story of the shrimp industry. Scientific Monthly, vol. 38, pp. 429–443, May 1934.
Fishery biology, its scope, development, and applications. The Quarterly Review of Biology, vol. 9, no. 3, pp. 275–291, September 1934.
HILDEBRAND, SAMUEL F.
The capture of a young tarpon, *Tarpon atlanticus*, at Beaufort, North Carolina. Copeia, no. 1, 1934, p. 45.
HILE, RALPH
Causes of variation in the growth rates of fishes. The Fisherman, vol. 3, no. 2, pp. 3–4, 10–11, March–April.
HILE, RALPH, and HILARY J. DEASON.
Growth of the whitefish, *Coregonus clupeaformus* (Mitchill), in Trout Lake, Northeastern Highlands, Wisconsin. Transactions, American Fisheries Society, vol. 64.
HILE, RALPH, and WM. R. DUDEN.
Methods for the investigation of the statistics of the commercial fisheries of the Great Lakes. Transactions, American Fisheries Society, vol. 63, pp. 292–305.
HOPKINS, A. E.
Accessory hearts in the oyster. Science, vol. 80, pp. 411–412.
Accessory hearts in the oyster, *Ostrea gigas*. Biological Bulletin, vol. LXVII, pp. 346–355.
LOCKE, S. B., and A. S. HAZZARD.
The fish of Utah. Utah—resources and activities. State Department of Education.
LORD, RUSSELL F.
Hatchery trout as foragers and game fish. Transactions, American Fisheries Society, vol. 64, pp. 339–345.
NEEDHAM, P. R.
Quantitative studies of stream bottom foods. Transactions, American Fisheries Society, vol. 64, pp. 238–247.
Notes on the food of trout. California Fish and Game, vol. 20, no. 2, pp. 119–127.
NEEDHAM, P. R., and A. C. TAFT.
Observations on the spawning of steelhead trout. Transactions, American Fisheries Society, vol. 64, pp. 332–338.

NESBIT, R. A.
A convenient method for preparing celluloid impression of fish scales. Journal du Conseil, vol. 9, no. 3, pp. 373–376.
The fishery conservation problems of Long Island. Fishing Gazette, vol. 51, no. 8, pp. 27 and 29, and Fishing Gazette, vol. 51, no. 9, p. 41.
PEARSON, JOHN C.
Marking fish. Louisiana Conservation Review, vol. 4, no. 2, pp. 30–33, April.
PRYTHERCH, HERBERT F.
The role of copper in the setting, metamorphosis, and distribution of the American oyster, *Ostrea virginica*. Ecological Monographs, vol. 4, no. 1, pp. 47–107.
Scientific methods of oyster farming. Scientific Monthly, vol. 38, no. 2, pp. 118–128; Atlantic Fisherman, vol. 15, no. 4, pp. 17–18; Fish and Oyster Reporter, vol. 15, no. 8, pp. 2–3, 10–11.
Rehabilitation of public oyster beds in North Carolina. Atlantic Fisherman, vol. 15, no. 2, p. 14.
Oyster parasite threatens production in Florida. Fishing Gazette, vol. 51, no. 13, pp. 11 and 27.
TAFT, A. C.
California steelhead experiments. Transactions, American Fisheries Society, vol. 64, pp. 248–251.
VAN OOSTEN, JOHN.
On the deep trapnet in the State of Michigan. [A letter, Dec. 13, 1934.] Michigan Tradesman, no. 2674, p. 25, December.
The value of questionnaires in commercial fisheries regulations and surveys. Transactions, American Fisheries Society, vol. 64.
VAN OOSTEN, JOHN, H. J. DEASON, and FRANK W. JOBES.
A microprojection machine designed for the study of fish scales. Journal du Conseil, vol. 9, no. 2, pp. 241–248.
WRIGHT, STILLMAN, and WILBUR M. TIDD.
Summary of limnological investigations in western Lake Erie in 1929 and 1930. Transactions, American Fisheries Society, vol. 63, pp. 271–285.

The following progress reports covering the more important investigations of the Division during the calendar year 1934 were prepared in the main by the investigators in charge of the various projects.

NORTH AND MIDDLE ATLANTIC FISHERY INVESTIGATIONS

The experience of the last several years of economic depression has brought into focus an aspect of the economy of our marine fisheries hitherto overlooked, but of great significance to the fundamentals of conservation of our marine resources. It is generally agreed among fishery biologists that few, if any, of our marine species can be reduced to extinction by overfishing. Rather, the effect of progressive depletion is to lower the level of abundance, to reduce the return per unit of fishing effort, to raise the cost of production, and to increase prices. Theoretically, this process might continue indefinitely so that the products become luxuries utilized only by the more affluent consumer. But this means practical extinction of the fishery as a commercial enterprise. Obviously, the industry must depend on reasonable volume, which, in the fisheries, can be had only while its products remain low enough in price to remain in the staple class. The optimum condition, of course, is found where the level of abundance is such as to provide a maximum continuing volume of yield. However, the experience of New England's fisheries in the past several years has brought to light another limitation; that is, the level of abundance must be such that fish can be pro-

duced at a cost that can meet price competition with meats. This was not demonstrated by depletion of fish to the point of raising costs of production but by the lowering of meat prices to such a point that fish could not compete successfully at the ordinary level of abundance and ordinary cost of production.

It is imperative, therefore, that there be developed means of observing the changing levels of abundance and bringing forces to bear to counteract trends in the dangerous direction. This is being done in the case of several of the most important species of this region, including haddock, mackerel, squeteague, and scup, as will appear in the following pages. But the staff and its facilities have been inadequate to cover other almost equally important species, among them the lobster, shad, flounders, sea bass, bluefish, and cod, not to mention some twenty-odd other species of lesser importance but constituting in the aggregate an important segment of the coastal and offshore marine fisheries.

Even the species receiving consideration cannot be accorded the amount of study that the problems connected therewith require for solution. The most serious handicap under which the staff is operating is the lack of a sea-going research ship equipped for trawling. It is badly needed to survey the stocks of young haddock, upon which the future of the trawling fleet depends; to operate experimental gear so as to develop means of saving young fish from needless destruction now attending certain methods of fishing; to catch live fish for tagging in order that their migrations may be followed; and to take observations on conditions of the sea water of our fishing grounds that determine the success or failure of future broods. Additional personnel is needed to perform field work and to assist in the analysis of the field data. The fisheries of the region provide products valued at $25,000,000 annually as landed at the dock. The annual expenditure for the research on marine fishery problems of the region is only one one-hundredth of 1 percent of the value. This rate is too low to provide adequate insurance against unwitting overexploitation on the one hand or unsound restrictions on the other hand.

As in former years, the staff, under the direction of O. E. Sette, has been provided with laboratory and library facilities by the Harvard Biological Laboratories and the Museum of Comparative Zoology at Harvard University, Cambridge, Mass., where its members have also benefited from consultation with members of the university, especially Henry B. Bigelow, professor of oceanography and director of the Woods Hole Oceanographic Institution, whose wealth of knowledge and experience relating to marine fisheries research has been ever at the disposal of the Bureau employees. It is a pleasure also to acknowledge the continued cooperation of fishermen and fishing companies in providing data essential to the progress of the work.

HADDOCK

In 1934 the fishing activities of the New England haddock fleet were extended over a much wider area than in previous years, yet the total haddock catch was little greater than in 1933. The landings at the principal ports (these include all landings except a rela-

tively small quantity at minor ports) reached about 135,000,000 pounds compared to 130,000,000 in 1933. However, for the first time in the history of the fishery the greater part of the catch came from the banks off the Nova Scotian coast (Sable Island, Banquereau), Browns, and La Have. The catch on Georges Bank (including South Channel and Nantucket Shoals), which in past years has averaged nearly 80 percent of the total United States landings, in 1934 declined to 40,000,000 pounds, the lowest in the history of the modern fishery, and but 30 percent of the total. The catch on the Nova Scotian banks by United States vessels reached 88,000,000 pounds.

The sharp decline in the Georges Bank fishery was the result of the continued poor fishing in this area, which caused practically all of the large trawlers and many of the large draggers to spend most of their time on the Nova Scotian banks. The great increase in running time to and from these more distant banks (Banquereau is about 625 miles from Boston, while Georges averages 180 miles) was more than compensated for by the greater catch per day's fishing.

The actual changes in the haddock population have been studied during 1934 along the lines described in previous annual reports. Investigation has continued under the direction of W. C. Herrington, assisted by J. R. Webster. Owing to a reduced staff and funds, field work has been confined almost entirely to the Boston Fish Pier where vessel interviews have provided information as to fishing time, fishing position, and other relevant data for practically all haddock trips landed. Extensive length-frequency data and scale samples were also obtained throughout the year from commercial catches made in each of the principal areas fished. F. E. Firth handled most of the work at the fish pier during the winter, and J. R. Webster or W. C. Neville during the summer, while Mr. Firth was assisting in the mackerel investigations.

Georges Bank and adjacent areas.—The haddock population in this area has been at a low level of abundance since 1929 and has shown little indication of recovery. In 1932 there was some improvement in the marketable stock caused by the growth to commercial size of the relatively numerous 1929 class. The gain was short-lived, however, for 1933 saw the level of abundance, as indicated by catch per day, again decline. This decline was caused by reduction in the stock through catch mortality (mortality due to the fishermen's catch) and natural mortality. The 1930 year class, which reached commercial size during 1933, was much too scanty to furnish sufficient contributions to the marketable stock to compensate for this mortality.

It has been mentioned that the 1934 haddock landings from Georges Bank amounted to only about one-half the quantity landed in 1933. However, this was due to the shift of a large part of the fishing effort to the Nova Scotian banks rather than to a decline in abundance on Georges. In fact, the catch per day for the first 8 months of 1934, as shown by our catch analysis, was some 15 to 20 percent higher than in 1933. (Figures for the balance of the year are not yet available.) There is some probability that this improvement in catch per day does not represent a proportional increase in

the marketable population. The number of boats on which the 1934 catch analysis is based was reduced to about one-half of the large otter trawlers, a reduction made necessary by a much curtailed staff. This reduction was made reluctantly after a careful analysis had demonstrated that during 1932 and 1933 the fluctuations in the average catch per day of the smaller group were representative of the entire fleet. But during 1934 the principal activities of the large trawlers were transferred to the Nova Scotian banks and the boats in question remained on Georges Bank only when fishing was relatively good. If catches were poor, the boats moved to the more distant banks. Consequently, the higher 1934 catch per day may be due partly to this selective fishery and not represent an equally great increase in abundance. Limited facilities have not yet permitted us to examine this possibility through the analysis of records of the smaller boats which regularly fish on Georges Bank.

There seems little doubt but that the size of the marketable stock of haddock on Georges Bank was somewhat greater in 1934 than in 1933, even though the increase was not as great as indicated by the catch-per-day figures. This improvement was due partly to the fairly good 1931 class which reached commercial size during the winter of 1933–34 and spring of 1934, and partly to the great decrease in the strain imposed on the stock by the reduced commercial catch. With only about half as much haddock caught out during 1934 as in the several preceding years, the population level was maintained and even somewhat increased with only moderate additions of young fish.

The success of the fishery on Georges Bank during any year—that is, the return for a given unit of fishing effort—is primarily dependent on two factors: (1) The rate at which the commercial stock declines as the result of catch and natural mortality (this is largely determined by the intensity of the fishery); and (2) the contribution to the commercial stock from the young haddock spawned 3 years earlier. Thus, the 1929 class boosted the catch in 1932; and the 1931 class, in 1934.

To make accurate forecasts for the fishery 1 or 2 years in advance it is necessary that the above-mentioned factors be known. With present facilities for observation it is possible to determine the rate of decline of a stock of fish once it has reached commercial size, providing it is possible to estimate the amount of fishing effort that will be expended in that area. However, we now have no means of determining how much an incoming year class will affect the commercial catch, for we have no observations by which we can evaluate the abundance of such year classes until they achieve commercial size and have been represented in the commercial landings for a period of nearly a year. Inasmuch as there are great fluctuations in the abundance of the different year classes, the annual contribution from this source is highly variable and is the most important factor in determining the fluctuating level of the fishery. The relative level of abundance in two general areas such as Georges Bank and the Nova Scotian Banks largely determines where the fishing fleet will expend their major efforts; consequently, it determines the intensity of the fishery in either area. Therefore, it follows that the level of abundance of the marketable stock during the course of any year is affected both directly and indirectly by the contribution of young

haddock to this stock. To estimate the size of this contribution a year or more in advance, it is necessary that it be possible to evaluate the abundance of haddock before they reach commercial size. For this work it is essential that a vessel be available for the collection of extensive samples of young haddock with small-meshed otter trawls.

An example of the limited reliability of forecasts based on present observations can be found in the 1933 annual report on haddock. That report discusses the probable course of the fishery on Georges Bank during 1934 and 1935. At that time it appeared that the catch per trawler day in 1934 would be somewhat less than in 1933. Actually the catch was somewhat better, due to the great reduction in fishing effort and to unexpectedly large contributions from the 1931 class, which it had been impossible to evaluate accurately until 1934, when it appeared in the commercial catch. Similarly, in the 1933 report the probability was expressed that the 1932 class was a failure and that consequently the fishery would continue to decline in 1935. Results of the fishery in the last part of 1934, however, indicate that the 1932 class is much larger than was supposed and may furnish a considerable contribution to the commercial stock. The abundance of this class cannot be determined from commercial-catch data until late in 1935. Consequently, at the present time it is impossible to make any predictions as to the 1935 fishery on Georges Bank except the general one that with fishing effort distributed as in 1934, the catch per day in 1935 probably will be considerably better than in the previous year.

Nova Scotian banks.—In 1934 nearly 90,000,000 pounds of haddock were landed from this area. This was about two-thirds of the entire United States catch and approximately twice as much as was ever before landed from these banks by the United States fleet. The actual level of abundance of commercial haddock, as shown by catch per day during the first 8 months of 1934, was about 10 percent higher than during the corresponding part of 1933. The increase was due to the 1929 class which came into the commercial fishery in the summer of 1933. (This same class on Georges Bank came into that fishery in the fall of 1931 owing to the faster growth rate in that area.)

The development of the fishery during the first 8 months of 1934 was much as anticipated in the 1933 annual report. At that time it was predicted that there would be an improvement in 1934 over 1933 in the catch per day during the spring and summer and a decline in the fall and winter. The spring and summer fishery has followed this trend although for various reasons the increase was not as great as was anticipated.

The fishery on the Nova Scotian banks should continue good in 1935 but somewhat below the 1934 level. However, this estimate can be no more than an approximation because of certain unevaluated factors. The 1931 year class will reach commercial size during the summer and fall of 1935 but it does not appear to be sufficiently abundant in this area to compensate fully for the decline in the present marketable stock owing to catch and natural mortality. Unfortunately, no reliable measure of the abundance of the 1931 year class is available due to the scarcity of information concerning the submarketable sizes. Our only basis for an estimate is a series

of length-frequency samples of unculled haddock obtained through the assistance of Messrs. Einar Sorenson and R. H. Blake, radio operators on two of the large otter trawlers.

Early life history.—One plankton and hydrographic cruise was made in April–May 1934, covering the area from Cape Cod and Nantucket Shoals to Browns and La Have Banks off the Nova Scotian coast. As in 1933 the trip was made possible through the kindness of the Woods Hole Oceanographic Institution in detailing the research ship *Atlantis* for this work. At each of the 64 stations oblique tows were made with a 2-meter stramin net and a ½-meter silk net. Vertical tows were made at some of the stations with a 1½-meter Helgoland larvae net or 1-meter silk net. Temperature and salinity data were obtained at each station and 629 drift bottles and 6 large drift floats released at stations and in strings. The 2-meter and ½-meter nets, used with current meters and the electrical inclinometer developed for this work, provided some rather definite data on the effects of clogging and change in towing speed. A cursory examination of the collections indicates that medium-sized haddock larvae were taken in the region southwest of Georges Shoals in greater numbers than at any stations on previous cruises. Drift bottle returns at the end of December 1934, totaled 64. About one-half of these were from the Bay of Fundy and but one-fifth from the United States coast west of Georges Bank. Four reports were received of positions of the drift floats, one float being reported twice. The surface drift as shown by these data appears similar to 1932.

During the past year L. A. Walford of the Harvard Graduate School completed the analysis of the egg and larvae collections of 1931 and 1932. The results show spawning concentrations on eastern and northern Georges and sometimes in the South Channel and clearly demonstrate the effect of water movements on the distribution of eggs and larvae. Evidence also is found that the southerly drift off Georges Bank such as observed in 1932 may be a factor in the failure of certain year classes.

Savings gear.—During the 5 years since 1929 the haddock population on Georges Bank has been held at a low level of abundance in spite of the contributions to the commercial stock from two fair year classes. The continued low level of abundance is the result of the intensive and destructive fishery that has developed in recent years. Although only those haddock weighing 1½ pounds or more are marketable, most of the commercial trawlers use nets which capture fish of all sizes from about one-fourth to one-half pound up. Nearly 2 years are required for the young haddock to grow from one-fourth pound to the marketable size of 1½ pounds. During this period they are constantly subject to decimation by the commercial fleet, and the millions that are thus destroyed constitute a complete economic and biologic loss and reduce the stock of fish on the banks to the same degree as the capture of equal numbers of large, commercially valuable fish.

An investigational report covering the results of the Bureau's savings gear experiments was submitted for publication during 1934. This work shows that the most practical method for reducing the destruction of undersized haddock is to increase the size of mesh used

in the otter trawls. A minimum cod-end mesh size of 4¾ inches (about 4⅛ inches after use) will capture only about one-fifth as many undersized haddock as the 3-inch mesh that generally has been used in the commercial trawls in the past. At the same time this mesh will lose less than one-tenth of the haddock between 1.5 and 2.0 pounds, and none above that size. The report recommends that the industry adopt a minimum mesh size of not less than 4¾ inches to be used in any part of the otter trawls except certain portions of the cod-end; e. g., belly and after end.

It is important that the recommendations of this report be followed by definite action. The trawler operators in general have recorded themselves in favor of the adoption of large-meshed nets, but for various reasons there has not been much consistent progress toward the use of such gear. A move for definite Federal or international regulation appears necessary for real progress. It is not a matter that can be postponed indefinitely, for already there has been a trend toward marketing the smaller sizes of haddock and once this practice becomes established it will be very difficult to obtain the adoption of large-meshed gear that will reduce the catch of such fish. The capture of small haddock, even though marketable, is a very short-sighted and irrational practice, for on Georges Bank 1 year's growth will cause a 1-pound haddock to nearly double and a half-pound haddock to nearly treble in weight; thus not only reaching a size that is of more value per pound but also increasing the actual poundage of fish in the ocean available to the fishermen.

In the light of present knowledge of the species the most practicable action that can be taken for the conservation of the haddock fishery is to leave the fish in the ocean during their early years of rapid growth and concentrate the fishery on the larger sizes where natural mortality approximately neutralizes the increase in the weight of the stock through growth. Such action would increase materially the catch that might be taken annually from the fishing banks. The use of mesh with a minimum size of 4¾ inches, as recommended, will protect most of the young haddock on Georges Bank until the end of their third year. This by no means is the ultimate to be desired, for a fourth year on the bank would cause a weight increase in these fish of about 70 percent, an amount that is much greater than the loss in poundage due to natural mortality. However, the recommended mesh size of 4¾ inches appears to be immediately practicable, and if acted upon would constitute a very considerable contribution to the future of the fishery.

The results of the United States and Canadian haddock investigations were presented at the 1934 meeting of the North American Council on Fishery Investigations. After a discussion of these results the council approved the report of the Committee on Haddock Investigations. Following are some of the more important recommendations:

> The committee endorses the opinion expressed at the general meeting of the council that the haddock problem has become of major importance to Canada and the United States (on the Atlantic coast); that immediate steps should be taken to adopt a common plan of investigation, which would adequately keep the situation under review and lead to the adoption of remedial measures.
>
> Further, the committee urges the adoption of a joint program of intensified research into the biology of the haddock, * * *.

The committee finds that existing facilities are quite inadequate to enable this broad program to be entered into. The prime essential is a suitably equipped research vessel, * * *.

Additional personnel will be essential in both countries, as far as the United States part of the program is concerned at least two fish measurers or quay men would be required to collect statistics of commercial catches, and a technical assistant would be necessary to assist in laboratory work and sorting of material.

It is recognized that, even by making such provision, the authorities will not provide for a full completion of the program outlined. Some aspects, especially those of the early haddock stages, will receive quite inadequate attention in the absence of the provision of a suitable research vessel.

It has not yet been possible to make a start on any of the projects of the joint program because of the unavailability of additional personnel or facilities.

MACKEREL

The paramount influence on the stock of mackerel in the sea (and consequently the size of the catch) is the variability in the degree to which annual recruits of young mackerel serve to offset the decline due to mortality of the older stocks. Since 1925 continuous observation of the catch and its age composition has proved that certain year classes, such as those of 1923, 1928, 1930, and 1931, were so plentiful as to more than offset mortality of the older stocks. Certain others, those of 1924, 1927, and 1929, were so poor that they did not fully counterbalance mortality of the adult stock; and still others, those of 1925 and 1926, were practically nonexistent.

These variations in numerical strength of the different year classes have been the dominating cause of all the fluctuations that have occurred in the last 9 years and have formed the basis of annual predictions on yield since 1928.

Although the ultimate causes of fluctuations—the conditions responsible for inequality of the year classes—remain unknown, it is fairly certain that they cannot be controlled by man, for they come into play while the mackerel are very young and before commercial fishing has any effect on them. There remains, however, the problem of making the best possible use of such year classes as the conditions in the sea permit to survive. This is being done in part by the predictions already mentioned for they permit the members of the industry to foresee, in general, the prospects for the coming season. Thus, the disorganizing effects of fluctuating supply can be minimized to the extent that the affairs of their business can be altered to meet the situation.

These predictions take into account only the general level of abundance for the season as a whole. In many ways it would be more useful to have foresight of what is to happen during the parts of the season. For instance, if scarcity were destined to prevail during the latter part of the season, freezing and salting could be accelerated during the early parts and vice versa. This would benefit the fisherman by expanding the market during times of glut and benefit the buyer by avoiding to a greater degree the understocking or overstocking of frozen and salted mackerel.

The third and perhaps most important question to be solved before the most effective use can be made of this resource is the relative value, biologically speaking, of the yearling mackerel. Following the advent of successful year classes, these are caught in large quanti-

ties. They are fairly small (½ to 1 pound each), have poorer keeping properties than the larger mackerel, and command a lower price per pound. At the same time they are growing fast and are destined to double in weight during the next year. It is appropriate, therefore, to inquire whether a partial or total elimination of the yearling mackerel from the catch might not be more than repaid by the larger size and the greater value per pound of these fish in future years. Essentially it is a question of whether apparent mortality (rate of disappearance as measured by the catch per unit time of fishing) is greater than the increase in value due both to increase in poundage and price per pound.

The answer to this question is complicated by the fact that the rate of disappearance of yearling mackerel differs greatly from one year to another and that the differences are connected not with the numbers caught out during the yearling year but with the type of year class to which they belong. There appear to be at least two types of mackerel in the western Atlantic; one, which we have designated as "persistent"; the other as "transitory." The former is characterized by a low rate of annual disappearance, the latter by a high rate. They are distinguished by other peculiarities such as the time and locality of greatest concentration and differences in rate of growth.

The existence of the two types with their different rates of disappearance not only renders difficult a decision as to the merits of exploiting yearling mackerel but also causes predictions to be less assured and less definite. It is essential, therefore, to determine the basis for the differences in behavior of these two subdivisions of the population and especially to find means of distinguishing between them at an early stage, in order to foresee their subsequent decline.

Naturally, the work during 1934 consisted of collecting and analyzing data necessary for determining the rate of catching and the year class composition of the commercial run. This has been and must continue to be the only means of appraising the current condition of the fishery. In addition, a new technique was employed to analyze the size frequency distribution of the 9-year period to throw more light on the nature of the two types of year classes, and the catch statistics were reanalyzed to discover whether the periods of presence of the two types were sufficiently distinctive and regular to serve as a basis of within-the-season predictions.

The work continued, as in the past, under the direction of O. E. Sette. Field data were collected by F. E. Firth. They consisted of 1,413 interviews to obtain information on time and locality of catches, measurement of 39,605 mackerel, and collection of 1,467 scale samples.

The prediction for 1934 was that the abundance would be the same as in the previous year and that the catch by seiners would amount to approximately 54,000,000 pounds if fishing were unrestricted, and proportionately less if control of production were to take place under provisions of the mackerel code. If these were to be of equal extent to those employed by voluntary agreement, a catch of 28,000,000 pounds was to be expected. Actually, production control was exercised during a smaller portion of the season and the catch was ac-

cordingly larger, being about 35,000,000 pounds. The level of abundance has not yet been estimated, there being extended computations required to adjust for the effects of production control on the measure of abundance. However, it appears that the abundance was practically equal to or slightly above the predicted level.

During 1934 O. E. Sette served as administration member of the executive committee of the Atlantic Mackerel Fishing Industry Code. The provisions of the code were effective in preventing the dumping and wastage of mackerel such as had occurred during the previous season but were less successful in substantially increasing the income of mackerel fishermen.

Lack of sufficient personnel has prevented progress during the year on the vital matter of finding out the nature of the two types of mackerel and the means of distinguishing them at a sufficiently early stage to be of use in forecasts, as well as to thrown light on the merits of exploiting yearling mackerel. This work would require large-scale tagging experiments at sea accompanied by examination of large numbers of mackerel from various areas and various portions of the season to discover whether there are reliable racial characters that distinguish the two types. Although it was impossible to include these particular items in the program, a small beginning was made on examination of mackerel for racial characters, but the numbers of individuals and the distribution of samples were far too limited to provide any conclusions.

If proper utilization of this important resource is to be attempted, it will be necessary to provide additional personnel both for field observations and laboratory analysis.

COD

Although the total catch of cod has not suffered a decline of the sort to cause concern over the future of this very important resource, there is good reason to suppose that the time may come in the not-too-distant future when heavier fishing intensity may have its effect. Even now the catch in southern New England, New York, and New Jersey waters is undergoing a severe decline, and we are ignorant of its cause or the remedies. Previous work has shown that this population is practically independent of the larger bodies of cod to be found from Georges Bank eastward to the Grand Banks, and it is possible that this southern segment of the species is undergoing a decline that should receive remedial attention.

For some years in the past the Bureau conducted large-scale tagging experiments on the cod which provided enlightenment on the relationships of the stock occupying the several grounds, showing that the southern segment was independent of all others, that the Maine coast was also primarily self-contained though acting as a feeder to the coastal waters of Nova Scotia and possibly to offshore grounds such as Georges Bank.

With the resignation of William C. Schroeder from the Bureau's service, this work ceased except for the analysis of returns currently received from tagging done during 1931 and 1932 which Mr. Schroeder has kindly continued to study and upon which he reports as follows:

Of 1,199 cod marked during 1931 with celluloid disks attached to the caudal peduncle and released off Mount Desert, Maine, 23.4 percent were recaptured

up to the end of 1932, 1.1 percent in 1933, and 0.3 percent in 1934. Of the total recaptures (24.8 percent), 90 percent were taken locally and 10 percent from distant localities. Of 1,481 cod marked during 1932 with celluloid strips inserted into the body cavity and released in the above-mentioned locality, 18.6 percent were returned up to the end of 1933 and 2.8 percent in 1934. Of the total returns of 21.4 percent, 91 percent were recaptured locally and 9 percent at distant points.

These experiments were undertaken in order to determine whether the young cod that predominate in the population along the shore migrate away from the shore as they grow older, thus serving to replenish the important fishing banks offshore. While these experiments have produced a higher proportion of distant recaptures than resulted from earlier experiments with less permanent tags, there does not appear to be any decided trend toward offshore recaptures as the fish grow older. To be sure, the fish involved in the experiment have not yet reached the age that is most common on the offshore grounds, and the experiment needs to run until they do reach such age before negative results become significant. However, the sharp reduction in returns threatens to reduce the numbers to the point of unreliability before this stage in the experiment is reached. It is believed that the sharp decline in returns from the 1931 releases is due to loss of the celluloid disks, and from the 1932 releases, to the belly tags becoming covered with mesenteric tissue so that they escape detection, especially on the offshore grounds where the fish are cleaned very hurriedly. Thus, it may be necessary to have further improvement in marking methods or to approach this question by another method, perhaps scale studies, in order to solve the problem.

At present the trawling fleet fishes mainly for haddock. Studies of the haddock resource (see above) make it appear certain that increased fishing will cause no considerable or sustained increase in the yield. This being the case, we can anticipate a more intense fishery for cod. In fact, there appears to be a trend in this direction already, and it is urgent, therefore, that studies of the condition of the cod resource be resumed. The most effective corrective measures are those that are applied before irreparable damage is done. Since the major portion of the fishery is carried on by a fleet of vessels which land their catches mainly at Boston, only a moderate outlay would be necessary to make the pertinent observations on the condition of this fishery along with those now made on haddock.

FLOUNDERS

The flounder fishery has assumed major importance during the last two decades. The various species of flounders are caught mainly by the smaller vessels of the otter trawl fleet commonly called "draggers." This type of boat has been increasing in numbers and concern is felt as to the capability of the resource to withstand the present intensity of fishing—so much so that several of the flounder-producing States have passed laws restricting the flounder fishery in various ways. Further restrictions are contemplated in at least one of these States. Although such restrictions are based on good intentions, they have not been preceded by any examination into the question of whether they will produce the desired results. No one knows whether the present sacrifices they impose will be compensated by future gains. In fact, little is known of the life history of the six species that make up the catch. Nothing is known of their rate of growth, the amount of migration from one region to another, or most important, to what degree the annual replacement compensates for removals by the commercial fishery and by natural mortality.

A single small experiment was undertaken in 1931 when some 4,000 winter flounders from Waquoit Bay were tagged and released. The returns in successive years from 1931 to 1934, inclusive, were 141, 64, 33, and 11. Unfortunately, we do not know what proportion of the decline in returns was due to loss of tags and what portions to mortality, but the results do not preclude the possibility that the rate of mortality of flounders is relatively high. The returns indicate that most of the Waquoit Bay stock returns there for spawning each winter, but during the summer they wander into the adjacent sounds and into the open sea beyond. During last season there was one return from Massachusetts Bay—the first indication that the flounders from south of Cape Cod may wander to its northern side. Previous distant returns were from Georges Bank to the east and from western Long Island to the west.

To formulate an effective conservation policy, it will be necessary to institute a series of observations similar to that employed in the case of the haddock and mackerel, whereby statistics are collected in such detail that an index of abundance could be computed in terms of catch per day's trawling. Field data for determining rate of growth and for arriving at the age composition of the catch from each important fishery area would need to be collected and studied, and additional tagging would have to be done to determine to what extent one locality is dependent on another for its stock. The distribution of the flounders is extensive so that observers would be needed at at least four ports. Thus, a staff of four members or more would be required for the field work alone and additional persons would be needed in the laboratory.

The need for undertaking this work is imperative. The total yield of flounders has already begun to decline (20 percent between 1929 and 1932) and several seasons must elapse before results from an investigation can be expected. If this fishery is allowed to retrograde too seriously before corrective measures are applied, either these will be more drastic than if applied earlier or the fishery will be stabilized at a lower level of yield than would otherwise need be the case.

SPECIES IN NEED OF ATTENTION

Lobster.—The lobster fishery has declined steadily in productiveness since the time that earliest statistical evidence is available. The present annual catch is but one-third as large as in 1889, and, in spite of the ever-increasing number of lobster pots in operation, the present rate of decline is 10 percent per annum. Consequently, the annual decrease in abundance must be substantially more than 10 percent.

The decline has persisted for years in spite of State laws intended to preserve the resource. These laws consist mainly of a limit on the size of lobster which may be sold legally. It is imperative to determine, by a survey of the lobster population, whether such size limits protect a sufficient percentage of the stock. Furthermore, since the regulations on sale of undersized lobsters have been found extremely difficult to enforce, it is further necessary to find some more effective means of securing the necessary protection. It is desirable, therefore, to test lobster pots designed to catch only certain sizes and introduce such modifications as are indicated by the tests. If such pots prove

satisfactory, both from the standpoint of catching efficiency and from the standpoint of excluding the protected sizes from the catch, a definite improvement in regulation could be attained.

After an initial survey has determined the percentage of the population to be protected by size limits or other means, a continuous observation of the effects of new regulations would be necessary to determine their adequacy.

SHORE FISHES OF THE MIDDLE ATLANTIC STATES

The shore fishes of the Middle Atlantic States (New York, New Jersey, Pennsylvania, and Delaware) are of especial interest because they not only support an important commercial fishery but also provide a basis for a sport fishery the magnitude of which is not generally appreciated. Quite aside from its recreational value, this sport fishery has commercial aspects of great importance. The business of catering to the needs of anglers (boats and guide service, transportation, tackle, and bait) has reached astonishing proportions and has become an important item in the economics of seashore communities in these States.

Investigations of these shore fishes were continued under the direction of R. A. Nesbit, assisted by W. C. Neville. As in 1933, reduction of appropriations necessitated severe curtailment of activity. Field work was limited to a single visit to producing areas in October and to a 3-month observation of the catches made by the winter-trawl fishery. Prof. A. E. Parr, curator of the Bingham Oceanographic Foundation, continued his studies of the early life histories of these fishes in southern New Jersey.

Squeteague.—By the end of 1933 satisfactory methods of investigation had been developed and enough of the data collected between 1927 and 1933 had been analyzed to permit a summary of the principal scientific findings with regard to the life history of the squeteague. In 1934, additional scale and length frequency data, secured in October, were analyzed, and additional tag returns were received. Also, a large part of the earlier scale collections were examined according to the circulus spacing method for determining origins and subsequent migrations. The results confirm and strengthen the views expressed in the 1933 report.

Since the conservation recommendations which follow are based on these scientific findings, it is desirable to summarize them briefly:

(1) Not more than one-half of the squeteague taken north of Delaware Bay are the product of local spawning. This view is based on the observation that not more than one-half of the northern squeteague have scales of the type characteristic of northern juveniles. It is possible that even these northern juveniles are the product of southern spawning, migrating to northern waters early in the first summer of their lives. This suggestion is based on the observations of Professor Parr. Although he has found squeteague eggs in several New Jersey and New York localities each year from 1929 to 1934, the larvae are uniformly absent from the collections. This is in marked contrast to the presence of larvae in Virginia and North Carolina waters as reported by Hildebrand and Cable (1934) and by Pearson (unpublished manuscript).

(2) Nearly all (90 percent or more) of the squeteague taken in the Middle Atlantic States are 2 years of age or older, and nearly all have passed their yearling summer south of Delaware Bay. This view is based on age analysis of large samples collected at various localities in New York and New Jersey between 1928 and 1934 and on the observation that the second (yearling) growth zones of the scales of virtually all northern market squeteague are of the type characteristic of the corresponding growth zones of southern yearlings. The conclusions drawn from scale studies are confirmed by tagging experiments.

(3) Yearling squeteague predominate in the southern catches. This observation is based on age analysis of samples taken by Higgins and Pearson in 1925 in North Carolina and of samples taken during the present investigation in Virginia and North Carolina in 1928, 1929, 1931, 1933, and 1934.

(4) Squeteague grow much more rapidly in the North than in the South. For example, squeteague at the end of their third summer average only 11 inches in length and 0.43 pound in weight south of Delaware Bay. In southern New Jersey they average 12 inches in length and 0.56 pound in weight and in northern New Jersey 13 inches in length and 0.75 pound in weight.

For a number of years restriction of both the commercial and angling catch of squeteague has been urged in New York and New Jersey. In New York such proposals have invariably been rejected by the legislature. In New Jersey a number have been adopted, among them prohibition of purse seining within 2 miles of the shore, restriction of the length of gill nets, specification of minimum mesh size for gill nets, and imposition of closed seasons for gill-net fishing in certain areas. Restrictions are usually urged on the ground that abundance may be maintained or increased in the future by protecting spawning adults.

In the light of our present knowledge of squeteague life history, it is apparent that restriction of the New York and New Jersey catch of adult squeteague cannot be expected to influence future abundance sufficiently to compensate for the immediate sacrifices required. As has been pointed out, the northern spawning stock is not wholly self-perpetuating but depends on southern spawning for at least half of its annual increment even if it be assumed that northern juveniles result from northern spawning. This means that of the fry resulting from the spawning of 2 northern adults, on the average but 1 weak fish returns to the North 2 years later. Consequently, in order to add 1 more weak fish to the catch in 1937, it would be necessary to refrain from catching 2 in 1935, obviously an unprofitable bargain, even if the cost of enforcing restrictive legislation be left out of account.

It is necessary to consider other measures if the present unsatisfactory conditions in the Middle Atlantic States are to be improved. The yield of squeteague in these States has declined from an average of 17,000,000 pounds per annum for the years 1901, 1904, and 1908 (years for which statistics are available), to an average of 12,000,000 pounds for the years 1926, 1929, 1930, 1931, and 1932. It is highly probable that this decline is in large part due to an increase in the catch of the southern fishery (Maryland, Virginia, and North Caro-

lina) from an average of 11,500,000 pounds per annum in 1901 and 1908 to an average of 18,000,000 pounds per annum for the years 1925, 1929, 1930, 1931, and 1932. It has been seen that virtually the only squeteague available to the northern fishery are those which escape the intensive southern fishery to which they are subject during their yearling summer. If the increase in yield in the South were due to increased abundance rather than to an increase in the percentage toll taken by more intensive fishing, it is to be expected that a similar increase would have occurred in the northern fishery.

It does not necessarily follow, however, that the most effective use of the squeteague resource requires restriction of the southern fishery. It is unwise to postpone capture of fishes beyond the point where natural mortality removes more pounds of fish than are replaced by growth. Since the investigation has not progressed sufficiently to make possible reliable estimates of natural mortality, it cannot be said fairly that the yearling squeteague taken in the south would be more valuable if spared for an additional year or more.

Although there is insufficient evidence to justify restriction of that portion of the southern catch which is actually utilized, the present destruction of juvenile and yearling squeteague too small to be marketed cannot be too strongly condemned. As pointed out by Higgins and Pearson (1925), this destruction may amount to as much as 30 percent of all squeteague taken. There can be no reasonable objection on the part of southern fishermen to elimination of this waste, for enough of the benefit would accrue locally to compensate for any inconvenience brought about by changed methods of fishing. It is urgent, therefore, that experiments be undertaken at once to devise modifications of the gear to permit the escape of undersized fish.

Scup.—Continued investigation of this species by W. C. Neville during 1934 has been concerned with determining the effect, if any, on abundance of the increased exploitation to which this species has been subjected since about 1929. As stated in previous reports, the rapid development since that year of a winter trawl fishery off the Virginia capes for scup, sea bass, and fluke has resulted in an additional strain of approximately 25 percent on the general stock of scup. The analysis, therefore, has been mainly a study of the fluctuations in the catch of both the summer and winter fisheries to determine whether the changes are related to the increased fishing activity.

It has been demonstrated clearly from tagging experiments and from the ages and sizes of the fish in the catch that the summer and winter fisheries are drawing on the same stock of scup. Tagging experiments have demonstrated that scup migrate in the fall from the summer fishing grounds along the shores of southern New England, New York, and New Jersey to the winter fishing grounds off the Virginia capes, and in the spring make a return migration from the winter grounds to the summer area. Analysis of the catches has disclosed that broods of scup that have been conspicuous in the summer fishery have constituted a large part of the catch of the southern trawl fishery in the following winters.

Observation on the summer fishery during 1934 was not possible, through lack of funds, so that nothing definite is known as to what age groups are supporting that fishery at the present time and as

to the degree of success of reproduction in 1933 and 1934. Analysis of catch-record data supplied voluntarily by pound-net operators, however, indicates a high yield of scup in 1934 continuing the series of record total catches this particular fishery has experienced each summer since 1929 (for the State of New Jersey the pound-net catch rising from 2,400,000 pounds in 1929 to 3,500,000 pounds in 1933), following a period of scarcity from 1926 to 1928, inclusive (500,000 pounds in 1926 to 300,000 pounds in 1928). The record yields of 1929–33 were the result of successful spawning each season from 1927 to 1932, with the exception of 1929.

Observations on the southern trawl fishery during the past winter (1933–34) showed that the catch of approximately 2,500,000 pounds of scup landed principally at Virginia ports was the highest in the history of the fishery. As in most previous winters, the size and age composition of the landed catches was similar to that usually observed in the summer pound-net fishery, consisting, in the main, of small and medium-sized fish (7 to 9 inches in length, averaging one-fourth to one-half pound in weight).

It was disclosed further, in accordance with previous winters' observations, that the catch of this southern winter trawl fishery is not only dependent on abundance but also on the degree of availability, which in turn is affected by changes in the hydrographic conditions of the general fishing region. It is now known that changes in water temperatures affect the movement of the schools, causing changes in the amount and in the size of fish caught.

Thus, as indicated above, the total yield of scup by the summer and winter fisheries continues at record levels due to a series of successful spawnings. This condition cannot be expected to continue indefinitely. Sooner or later a series of spawning failures similar to those which caused the natural decline between 1926–28 will occur.

It is but prudent, therefore, to prepare for this condition by correcting existing abuses which may accelerate the inevitable decline or endanger the chances of natural recovery. The most conspicuous abuse is unnecessary destruction of young fish both in the winter trawl fishery and in the summer pound-net fishery. During the past winter the southern trawl fishery discarded at sea large quantities of small scup consisting in part of fish below legal limit and in part of small but legally marketable fish for which, under the economic conditions of last winter, no market could be found.

It is estimated that for a total catch of approximately 2,400,000 pounds of scup landed by vessels at Virginia ports in January, February, and March, more than 500,000 pounds or 20 percent were discarded at sea. Expressed in numbers of fish it means that of a total catch of approximately 4,700,000 scup, about 1,900,000 fish or 40 percent were destroyed and discarded. It is probable that an even larger proportion of the catch of vessels landing at ports in New York and New Jersey was discarded since the smaller sizes of fish are less readily marketable there.

Less definite figures are available for the pound-net fishery, particularly in recent years, but the waste is known to be great in the summers following the advent of large broods.

The advantages to be derived from reduction of this waste are as follows: (1) Since the fish now destroyed have no value, a clear

gain will be realized from those allowed to escape and grow to marketable size, even though reproduction continues to be successful for several years; and (2) when reproduction fails during a series of years (as experience indicates is inevitable), young fish thus spared will be doubly valuable, for they will increase the spawning reserve necessary to insure eventual natural recovery and they will augment the stock available to the fishery during the period of scarcity.

It is desirable, therefore, that experiments be conducted to determine the practicability of extending to the Middle Atlantic pound-net fishery the practice of sifting out small scup now generally used by operators of floating traps in Rhode Island. It is also desirable to reduce the waste of young fish in the winter trawl fishery by introducing changes in the mesh of the cod-ends of the trawls. Considerable experiment will be necessary to determine the correct sizes, for the problem is complicated by the fact that more than one species must be considered (in addition to scup, sea bass and fluke demand attention). Lack of funds has prevented experiments thus far, but it is urgent that they be undertaken at the earliest possible date.

Other species.—A number of important species have perforce been neglected during the course of Middle Atlantic investigations. Among them are sea bass, bluefish, and shad. Since bluefish and sea bass are taken to some extent by the summer pound-net fishery and sea bass constitutes an important part of the catches of the winter trawl fishery, advantage was taken of the opportunities to collect many data bearing on them at times when field observations were being made of the catches of squeteague, scup, and butterfish by these fisheries. Because of insufficient personnel it has been impossible to analyze the data collected and impossible to arrange for observations of the hand-line fisheries for bluefish and sea bass, and the lobster-pot fishery for sea bass. It is particularly urgent that investigations of sea bass be undertaken, for this species has been subjected to a greatly increased fishery strain through the rise of the lobster-pot fishery and the winter trawl fishery in recent years.

The shad fishery in the Delaware River has practically disappeared. In 1897 the yield of this fishery was 16,098,552 pounds, valued at $436,546. In 1932 the yield had shrunk to 109,979 pounds, valued at $15,469. Even if we assume that the yield in 1897 was excessive and that under proper management the fishery is incapable of a constant yield of more than half of the quantities caught in 1897, it is apparent that the destruction of this fishery is causing an annual loss of more than $200,000 to the communities concerned and is depriving the consuming public of approximately 8,000,000 pounds of very desirable food. It is probable that pollution and obstruction of streams is in large part responsible, for in spite of very intensive fishing the yield in the less highly industrialized Chesapeake States has not diminished so severely. It is urgent, therefore, that rehabilitation be undertaken in accordance with the authorization provided by Public Law No. 121, Seventy-third Congress, March 10, 1934.

It is also desirable to seek means of restoration of the shad fishery in other localities where the destruction is not yet complete. The present yield in the Chesapeake States and in the Hudson River is

greatly reduced as compared with earlier years. Biological studies of shad life history, statistical study of fishing intensity, and pollution studies will be necessary to indicate the best procedure for rehabilitation and management of these fisheries.

FISHERY INVESTIGATIONS OF THE SOUTH ATLANTIC AND GULF COASTS

INVESTIGATION OF THE SPAWNING HABITS, LARVAL DEVELOPMENT, AND RATE OF GROWTH OF FISHES

The study of collections of young fish and field data collected principally on the coast of North Carolina was continued intermittently, as other duties permitted, by Dr. Samuel F. Hildebrand and Louella E. Cable. Additional specimens were obtained from Beaufort, N. C., and vicinity from towings made by Dr. James S. Gutsell in his study of the life history of shrimps. Several nearly complete and some partial series showing stages in the development were identified. Drawings, and in some instances descriptions, have been prepared.

SURVEY OF THE FRESH WATERS OF MISSISSIPPI

A general survey of the fresh waters of Mississippi was begun by Dr. Hildebrand in 1933. Although it was not found practicable to continue the field studies in 1934, considerable time was devoted to a study of the collections obtained the previous year. A special study of the minnows of the family Cyprinidae was made. Thirty species were recognized in the collection, and descriptions with notes on their life histories and habits have been prepared. Nearly all of these minnows are of importance because they constitute the chief food for many food and game fishes.

MARINE FISHES OF THE GULF COAST

Systematic studies of the fishes of the Gulf coast were continued by Isaac Ginsburg. Special attention was given to the families *Pleuronectidae*, *Gobiidae*, *Cyprinodontidae*, and *Syngnathidae*. In connection with this work the revision of a number of genera of American gobie is being prepared, which should be of help in placing the systematics of the *Gobiidae*, one of the most difficult families of American marine fishes, on a firm scientific foundation.

AN INVESTIGATION OF THE FISHES AND FISH CULTURAL POSSIBILITIES OF THE FRESH WATERS OF PUERTO RICO

An investigation of the status of the fishes of the fresh waters of Puerto Rico and the fish cultural possibilities existing there was undertaken by Dr. Samuel F. Hildebrand in cooperation with the Insular Department of Agriculture and Commerce. The principal fresh waters of Puerto Rico consist of 5 main streams with tributaries and 6 permanent reservoirs. Fishes in general are scarce in these waters. The indigenous fresh-water fishes consist almost wholly of representatives of salt-water families that in the course of time have

acquired a fresh-water habitat. These fishes disappear almost completely from the streams above an elevation of from 1,500 to 2,000 feet.

Food for fishes, consisting principally of crustaceans and insects, is abundant almost everywhere. The temperature of the waters at an elevation of 2,000 feet and higher is cool enough for rainbow trout, as it rarely exceeds 70° F. About 10,000 rainbow trout fry were hatched in the Loquillo National Forest from eggs received from the Division of Fish Culture through the United States Forest Service. Some 9,000 of these fry were liberated in streams within the forest while the remaining 1,000 were retained and fed principally on shrimps from the local streams. Whether the ones that were liberated have survived is not definitely known, but the ones retained and fed in captivity made fairly rapid growth.

Some bluegill sunfish (*Lepomis incisor*) and catfish (*Ameiurus melas*), presumably acquired through the New York Academy of Sciences, were introduced in two reservoirs in about 1913. These fishes have propagated and still are present in the two reservoirs in which they were introduced. A third species, one of the crappies (Pomoxis) also was introduced, and is said to have maintained itself, though it was not seen during the investigation. The introduction of temperate-zone fishes seems to have been so successful that more trout eggs and small bluegill sunfish (*Lepomis incisor*) and catfish (*Ameiurus nebulosus*) were sent during October and December 1934. The prospects that these American fishes will establish themselves are favorable, and it is hoped thereby to furnish sport and food for the people of Puerto Rico.

SHRIMP INVESTIGATIONS

The shrimp investigations have continued under the direction of Milton J. Lindner. As in the past, headquarters have been maintained in New Orleans, La., in offices furnished by the Louisiana Department of Conservation. Field stations have been located at the United States Fisheries Biological Station, Beaufort, N. C.; the Georgia Tidewater Commission, Brunswick, Ga.; and the San Patricio Canning Co., Aransas Pass, Tex. The Louisiana Department of Conservation; the Texas Game, Fish, and Oyster Commission; the Georgia Department of Game and Fish; and the San Patricio Canning Co. have continued their generous cooperation as in the past. Due to lack of funds, operation of the *Black Mallard* was interrupted on August 1, 1934. Operations of this vessel will be resumed for a brief period beginning January 1935.

In conjunction with the work of the Bureau the Louisiana Department of Conservation has been conducting a hydrographical survey of Louisiana waters under the direction of James Nelson Gowanloch.

The shrimp is the most valuable fishery resource of the South Atlantic and Gulf coasts. In 1932, the latest year for which statistics are available, the shrimp fishery, with a catch of over 88 million pounds and a value to the fishermen of over 2 million dollars, ranked sixth among those of the United States and Alaska. There are three species of shrimp that constitute the commercial catch, the common shrimp, *Penaeus setiferus;* the grooved shrimp, *P. brasiliensis;* and

the sea-bob, *Xiphopenaeus kroyeri*. The common shrimp is by far the most important because it comprises at least 95 percent of the commercial catch.

From a commercial standpoint, the shrimp fishery is in better condition than it has been in the last few years. Indications are that the pack of canned shrimp during the 1934–35 season will be larger than in the past several years with the market price holding up well. A closer organization of the canners and more cooperation between them was noted during 1934. The inauguration of the inspection system under the Pure Food and Drug Administration and the work of the shrimp section of the National Canners Association have resulted in a much improved pack of shrimp. The increase in the pack probably will cause a similar augmentation in the total landings of shrimp.

Because of the importance of the common shrimp, the major efforts of the investigation have been directed toward solving the problems presented by this species. The length measurements and gonad examinations show that the common shrimp reach maturity and spawn within 1 year. Not many spent shrimp are found and no shrimp which can be interpreted as being 2 or more years old has been taken. It is assumed from this that the shrimp die after spawning and that very few, if any, survive to spawn the following year. The spawning of the common shrimp occurs throughout the spring and summer in the open sea or Gulf, and the shrimp after hatching and passing through the larval stages move into the inside waters. These warm shallow sounds, bays, bayous, and rivers serve as nursery grounds. The young shrimp grow very rapidly and by June or July, depending upon the locality, attain sufficient size to appear in the commercial catch. By September almost the entire catch is composed of young shrimp from the spawning of the preceding spring and early summer. With the cooling of the waters in the early fall and winter there is a definite disappearance of the larger of the young shrimp from the inside waters and in some sections of the coast from the customary outside fishing grounds which, with few exceptions, are usually near the mouths of the passes.

At Beaufort, N. C., Dr. J. S. Gutsell has continued his studies of the structure and development of the ovarian eggs of the commercial species of shrimp. This study is of importance in determining just when spawning occurs and if a shrimp spawns more than once. Sections of many ovaries, including a number from the common shrimp with spermatophores attached, have been microscopically examined.

Because so few of the common shrimp are taken with spermatophores attached and because of the method of attachment, it seems certain that the spermatophores are not present on the female until they are ready or very nearly ready to spawn. Therefore, the large eggs found in the enlarged ovaries of all shrimp of this species with spermatophores attached are believed to be not only fully developed but also in a mature condition ready for emission and fertilization. Examination of such mature eggs reveals certain definite and distinctive structures in the yolk. These are not artifacts for under favorable conditions they may be seen in fresh eggs immediately after removal from newly killed shrimp. By proper fixation and staining they may be preserved and studied in sections which afford a superior picture of conditions within the ovary. One type of cytoplasmic body

does not appear until the eggs are fully grown. By means of it a substantially matured egg may be positively identified. This is of importance, for if examination of an ovary shows that this structure is present in the crop of large eggs it may be stated without any doubt that the shrimp is ready to spawn; thus, with proper sampling, the spawning season can be determined with precision.

In addition, Dr. Gutsell has examined a number of shrimp which appear to have recently spawned. From these studies he has secured ovarian characteristics which apparently are diagnostic of spent shrimp. This is a particularly important and valuable contribution. Dr. Gutsell is preparing a detailed report of these investigations which he expects to have completed before the end of the 1935 spawning season. The completion of the report is expected to terminate the study of this particular problem.

Mr. Anderson, during 1934, continued the sampling of the shrimp population along the South Atlantic coast aboard *Launch 58*. The territory sampled represents about 95 percent of the shrimp fishery on the Atlantic coast. For the purposes of this investigation, 9 outside and 2 inside stations were visited once each month and from 2 to 4 trawl hauls were taken at each station. The outside stations are from 35 to 50 miles apart and extend from Cape Romain, S. C., to Cape Canaveral, Fla. The stations were so chosen as to give a representative sample of the shrimp population at the more important fishing centers along this coast. At each station otter trawl hauls and plankton tows were made, surface and bottom temperatures recorded, and salinities determined. A representative sample of the shrimp obtained was measured, the development of gonads noted, and the numbers of each species of fish secured were recorded.

Confirmation of last year's data was obtained which indicated that the large shrimp disappear from the usual fishing grounds during the fall and winter along the Georgia and northern Florida coast. Similarly, confirmation was also secured for last year's data which indicated a progressive increase in size of the common shrimp from north to south along the Florida coast during the fall and winter. Four possible interpretations may be placed upon these phenomena:

1. There is a southward movement of the larger shrimp along the Florida coast during the fall and winter.

2. The larger Georgia and northern Florida shrimp move offshore during this period.

3. Due to heavy fishing in the summer and early fall, the larger shrimp are depleted along the Georgia and Florida coasts.

4. Combination of any two or all three of the above factors may be occurring.

As a possible means of interpreting these changes in the population of the shrimp on the South Atlantic coast, Mr. Lindner has been conducting racial studies at frequent intervals in four widely separated localities. Although these studies have not been completed, it has been found that there are differences in body proportions in the shrimp in different localities. A complicating factor arises in that these differences appear to be associated not only with locality but also with season of the year and age of the shrimp. An important discovery resulting from this study has furnished a means of distinguishing between 0 group and I group shrimp during the late summer and early fall.

Kenneth H. Mosher continued sampling the commercial catch of shrimp at Aransas Pass through the calendar year 1934. In 1933 the sampling was extended to include the commercial catch at four other Texas ports—Galveston, Palacios, Port Lavaca, and Port Isabel. The shrimp fishing at Palacios, Port Lavaca, and Port Isabel was so irregular that these three ports were disregarded in 1934, leaving only Aransas Pass and Galveston as regular sampling localities. During 1934, 20,516 shrimp were sexed, measured, and sexual maturity noted. Only 145 of the total measured were *P. brasiliensis* and only 71 were *Xiphopenaeus kroyeri*, or the two species taken together were only slightly over 1 percent of the total yearly sample. The remaining 20,300 shrimp were *P. setiferus*. In addition to the routine sampling, a number of the shrimp were weighed as well as measured in order to obtain the weight-length relationship.

After many unsuccessful attempts to keep shrimp alive for any length of time in various types of live boxes and aquaria, two pens were devised and placed in a small pond separated from Redfish Bay by a dike in which screened sluiceways were built to provide a current of water to the pond.

Early in December Mr. Lindner and Mr. Mosher initiated tagging experiments upon some shrimp placed in the pens. The celluloid disk or button tag was used. Although inclement weather caused the death of the shrimp a few weeks after tagging, the results were encouraging as it was evident that the shrimp were able to withstand the rigors of handling while being tagged. Mr. Mosher will continue these experiments as soon as the danger of freezing has passed.

Studies on the spawning and early growth of the commercial peneid shrimps have been continued by John C. Pearson. A unique discovery during the year was the recognition of the eggs of a peneid shrimp, probably *Penaeus setiferus*. These eggs, taken off the coast of Georgia on June 17, 1932, in surface plankton, appear to be the first peneid shrimp eggs to be secured in a pelagic state. The eggs were spherical in shape and possessed an extremely thin delicate membrane. The diameter of the eggs ranged from 0.38 to 0.42 millimeter. Within each otherwise transparent egg rested a well-developed nauplius, the length of which ranged from 0.21 to 0.26 millimeter. The capture of these eggs at the surface in water of 30-foot depth would indicate that the eggs were spawned relatively close inshore and that they are strictly pelagic, floating at the surface of the sea.

Nauplii, zoae, and mysis stages of the commercial peneid shrimps have been abundantly secured in many plankton collections off the coasts of Louisiana, South Carolina, Georgia, and Florida. Zoae and mysis stages of both the commercial shrimps, *Penaeus setiferus* and *P. brasiliensis*, are at hand and are being studied in detail with respect to morphological distinctions and oceanic distribution as to time and place. It is hoped that a report on the morphology and distribution of the young of these commercial shrimps can be completed during the coming year. Considerable material on the young stages of various noncommercial shrimps has also been collected with the studies of the commercial shrimps.

PACIFIC COAST AND ALASKA FISHERY INVESTIGATIONS

The major salmon and herring investigations have been continued through 1934 with some restrictions and limitations as to territory covered. During the year three new investigations were established; namely, the Columbia River salmon investigation, the Washington coho salmon investigation, and a detailed statistical study of the catches of all species of salmon from 1897 to 1933 in Puget Sound, the Fraser River, and Swiftsure Bank. The most severe limitation of activity has occurred in Alaska where the investigations have been confined mainly to the species of most economic importance; namely, the red salmon and the pink salmon.

COLUMBIA RIVER SALMON INVESTIGATION

In July 1934, the Division of Scientific Inquiry was allotted the sum of $25,000 annually during a 10-year period for scientific studies and experiments relative to the salmon fisheries of the Columbia River. J. A. Craig, formerly engaged in a study of these fisheries, was placed in charge of the investigation. Mr. Craig is being assisted by A. J. Suomela, who has also had experience on the Columbia River.

The object of this investigation is to provide information and recommendations which will point the way to the conservation of these important fisheries and provide for their productivity in the future. With this purpose in mind, a comprehensive program for the investigation has been prepared.

The development of the lands in the Columbia River Basin has been attended with many activities, such as the construction of dams and irrigation diversions and the introduction of sources of pollution, which, coupled with the intensive commercial fishery, have placed a great strain on the salmon populations of this river. In order to obtain some measure of the effect of this strain on the abundance of these populations it is necessary to conduct a detailed analysis, on the basis of catch return per unit of fishing time and effort, of the catch statistics of the salmon fisheries. It is known that the "run" of blueback and chinook salmon into the Columbia River is composed of a great number of races, each spawning in different tributaries and having fairly definite times for entering the commercial catch. The statistical study should yield information regarding the status of these separate races, as well as that of the composite runs of these two species. The statistical analysis, therefore, becomes one of the most fundamental and important parts of the present program of investigation.

In order to secure exact information on (1) the location and extent of the spawning areas now available to the salmon, (2) the location and extent of the spawning areas which have been destroyed and the causes of their destruction, and (3) the general status of the salmon populations spawning in the Columbia River at the present time, a program of stream surveys has been undertaken. Field parties have been sent out to cover the entire Columbia River system as rapidly as possible in order to determine the above-mentioned facts. It is hoped to discover the present condition of these spawning areas and to bring out facts which will lead to their improvement and rehabilita-

tion. The results of these surveys will also be a means of indicating which of the tributaries are suitable for transplanting or restocking projects.

The program for the investigation also calls for studies of the life history, habits, and homing instincts of the several species of salmon. All of these facts must be known in order to conserve the fishery properly.

During the period from July 1934 to January 1935, inclusive, a large number of catch records have been collected and their analysis carried forward with the aim of preparing a report on the indices of abundance of the chinook and sockeye salmon from 1905 to the present time.

The stream-survey parties, although handicapped by adverse weather conditions during a great part of the time while in the field, have covered parts of the Wenatchee, Entiat, Methow, and Okanogan River systems as well as Wenatchee, Silver, and Osoyoos Lakes.

PUGET SOUND SOCKEYE SALMON INVESTIGATION

The activities of this investigation in 1934 were continued on the basis of the previous year's program. Thousands of sockeye salmon fingerlings from the Birdsview hatchery were marked by the removal of two fins and liberated in each of three creeks tributary to the Skagit River. The object of this experiment was to determine something concerning the mechanism of the homing instinct in the sockeye salmon. If these fish are attracted to a stream by some property of the water in which they were reared they should enter that stream no matter whether they have traversed it before or not. On the other hand, if they return by some sense of geographical location they should return to the stream in which they were liberated even though they left it immediately.

With this theory in mind, 10,000 marked sockeyes were liberated in Bacon Creek, 10,000 in Day Creek, and 10,000 more in Diobsud Creek. All of these streams are tributary to the Skagit. Two enter this stream above Grandy Creek, where the fish were reared, and one below Grandy Creek. Different marks were used for each group of fish, and these fish were liberated at their natural time of migration. If it becomes evident that sockeyes will not return to a stream in which they were liberated at their time of migration and which they immediately left, additional experiments will be performed to find for what length of time it is necessary to hold fish in a stream in order that they become imbued with the urge to return to that stream.

Approximately 14,000 sockeye fingerlings were marked and liberated at the Quilcene hatchery. These fish were transferred from the Birdsview hatchery in the eyed egg stage. The marking was for the purpose of determining whether or not sockeyes will return to Quilcene, which is not a sockeye stream, after being reared there. The returning adults will be detected in the commercial catch in Puget Sound and so provide a check on their survival if none appear at Quilcene.

Scale samples from the commercial catch at Bellingham, Wash., were collected, and marked fish were secured in cooperation with the British Columbia investigators during the past fishing season.

Statistics of the sockeye salmon fishery were collected and tabulated during the first half of the year. In July J. A. Craig, who was in charge of this problem, was transferred to the Columbia River investigation and Dr. G. A. Rounsefell was placed in charge. Dr. Rounsefell, in collaboration with G. B. Kelez, was engaged in preparing a preliminary report on the statistics of the salmon fisheries of Puget Sound during the last half of the year.

WASHINGTON COHO SALMON INVESTIGATION

In January 1934 a new investigation on the coho salmon of Puget Sound and the coastal district of Washington was started under the direction of George B. Kelez. The purpose of this investigation was the determination of the life history and state of abundance of this species, which not only contributes materially to the commercial fisheries of this region, but also forms a large part of the catches of the recreational salt-water fishing.

A survey was made of the location and extent of the fisheries for this species and the location and size of the streams in which they spawn. During the early spring, sampling was carried on for yearling fingerlings resident in the streams, and the presence of fry hatched during the year was noted. Collections of scales from adult fish were made at Bellingham, Wash., at regular intervals during the months of June to September (through the cooperation of the Puget Sound sockeye investigation). Collections of scales from both immature and mature fish in sport-fishing catches and from adult fish in the commercial catches landed in Seattle from Cape Flattery and Puget Sound were also made. Through the cooperation of several fishing resort owners, records were obtained as to the abundance of various sizes of cohos in inside waters during the past season.

A series of marking experiments was undertaken to secure information on life history, homing instinct, and migrations of the species; the fingerlings being supplied through the courtesy of the Washington State Department of Fisheries. Twenty-six thousand fry hatched at the Samish station in February were marked during May by the removal of the adipose and dorsal fins and liberated in Friday Creek, a tributary to the Samish River. At the same time 10,000 fry from the Skykomish station (which is located on an independent stream system) were moved to the Samish station and marked immediately by the removal of the adipose and left ventral fins. These fish were also liberated in Friday Creek in an attempt to determine the effect of transplanting the fry on their choice of the stream in which they will spawn. A portion of the Samish fry, from which those marked in May were taken, were held in the Samish ponds until November, and an additional lot of 26,000 were marked at that time by the removal of the dorsal and left ventral fins. The comparative returns from the two Samish experiments are expected to demonstrate whether or not the additional period of

pond rearing will contribute materially to the resistance of the fingerlings to disease and natural enemies. Because of the vigorous growth and low mortality exhibited by these fish during the period of pond rearing, the State department of fisheries has determined to continue this procedure next summer wherever practical at the rest of their stations.

STATISTICAL STUDY OF SALMON FISHERIES IN PUGET SOUND REGION

During the latter half of 1934, Dr. Rounsefell and Mr. Kelez, in charge of the red salmon and coho investigations on Puget Sound, collected a great mass of statistical data of the catches of salmon of all species by all types of gear in the Puget Sound region as well as from Swiftsure Bank and the Fraser River. This included daily lifts of salmon traps from 1897 to date, of daily seine boat deliveries both from Puget Sound and from Swiftsure Bank from 1912 to date, and individual gill-net catches of over half of all of the gill nets operating on the Fraser River from 1929 to date. Several important features of the fishery were so well covered by these data that a preliminary report was made entitled, "Abundance, seasonal occurrence, and development of the salmon fisheries of Swiftsure Bank, Puget Sound, and the Fraser River."

This report gives a brief summary of the history and development of each type of fishing gear, where it has been fished, and the numbers used. The earliest fishery was chiefly with gill nets in the Fraser. Later came traps and small inefficient purse seines in Puget Sound. The purse seines increased steadily in efficiency after the introduction of gasoline motors in 1903 until the present modern Diesel-powered boat was reached. The amount of fishing gear reached its peak during the World War, descended to a very low level from 1922 to 1924, and then increased slowly but steadily to date. The ocean fishing on Swiftsure Bank with purse seines began in 1911 and quickly reached large proportions.

Studies of the seasonal occurrence of each species of salmon showed that in the traps in Puget Sound the king salmon run very early, 50 percent being taken before the others have really commenced to appear. The red salmon run next, followed a month later by the pinks. The cohos and chums run later than the rest. In the purse seines in Puget Sound all species are taken somewhat later than in the traps. This is especially true of the chums. On Swiftsure Bank most of the species are taken at the same time as in Puget Sound, with the exception of the cohos. Large schools of feeding cohos in their third year that are only half as large as they would be if caught later in the season are purse seined early in the season. The number of cohos on the bank fall off as the catches of larger cohos increase inside of Puget Sound. In the Fraser River the season is somewhat more extended than in Puget Sound and the fish appear to run later.

A detailed study of abundance shows that the red salmon, although not as abundant in the "big" year cycle as formerly, appear on the whole to be increasing gradually since the low point reached during the period 1920 to 1925 resulting from the combination of overfishing during the World War, and the blockade of most of the spawning grounds in 1913 and 1914 by the slide in Hell's Gate Canyon.

The coho salmon are less abundant at present than at any time since the beginning of the fishery. It appears that they are in need of more stringent protective regulations.

The pink salmon, although maintaining a fair level of abundance since 1915 are in no wise as abundant as in 1911 and 1913, before the slide of 1913 in Hell's Gate Canyon completely wiped out the population spawning in the Thompson and Nicola Rivers and the tributaries of Seton and Anderson Lakes.

KARLUK RIVER RED SALMON INVESTIGATION

The Bureau of Fisheries early realized the necessity of obtaining information on the number of red salmon that should be permitted to spawn in the streams in order to produce returns that would provide the maximum surplus for the fishery. Since this involved a study of the complete returns from known spawning escapements, a stream had to be selected where both the portion of the run taken for commercial purposes and the portion escaping to the spawning grounds could be determined. The Karluk River on Kodiak Island was the first stream selected for this study since it supports a large red salmon population which is subject to commercial capture only in the vicinity of its mouth. Furthermore, the Karluk River is centrally located in a large red-salmon-producing area, and it was hoped that the fundamental facts secured from the study of its fishery could be applied generally to the fisheries of the other red-salmon-producing areas in Alaska. This investigation has been carried on continuously each year since its inception in 1921, and at the present time is being conducted by J. T. Barnaby, assisted by L. D. Townsend.

The information available to date on the returns from known spawning escapements in the Karluk River indicates that wide fluctuations may be expected in the rate of reproduction of its spawning populations. During the past year a complete analysis was made of the returns from the known escapements of 1921 to 1928. The escapements for these years are as follows: 1921, 1,500,000; 1922, 400,000; 1923, 694,579; 1924, 1,000,000; 1925, 1,620,927; 1926, 2,533,402; 1927, 872,538; and 1928, 1,093,817. The ratio of return to escapement for these years is as follows: 3.0 to 1, 5.6 to 1, 2.9 to 1, 0.8 to 1, 1.0 to 1, 0.6 to 1, 1.8 to 1, and 2.1 to 1, respectively. The smallest escapement, 400,000 fish, produced the greatest return per spawning fish, 5.6 to 1, whereas the largest escapement, 2,533,402 fish, produced the smallest return per fish, 0.6 to 1. In other words, there seems to be little opportunity of selecting a spawning escapement that will consistently produce a large population.

In 1926 a series of marking experiments were established for the purpose of determining the mortality of the red salmon during their life in the sea. These experiments have consisted of the marking of 50,000 seaward migrants each spring. The proportion of the adult salmon bearing the marks that have returned from each experiment indicates that although the mortality in the sea is considerable it seems to remain fairly constant from year to year. However, the rate of growth of the salmon in the ocean varies considerably and is responsible for the length of time the fish from different

brood years remain in the ocean before returning to spawn. Obviously, salmon staying an extra year in the ocean before returning to spawn are subject to a greater mortality since they are exposed to the factors which affect their mortality for an additional year's time. Hence the wide fluctuations in the rate of reproduction of the spawning populations may be due in part to fluctuations in their ocean mortality.

Evidence was secured during the past season which indicates that changes in the natural conditions in the streams and lakes during the spawning period and early development of the salmon can bring about wide fluctuations in their mortality. In fact, the relatively poor returns from the escapements of 1924 to 1928, inclusive, are probably due to the abnormal conditions which were observed on the spawning grounds in 1924 and 1926. Hence it is believed that the varying rate of reproduction of the spawning populations may be traced largely to the success or failure of the spawning salmon and the death rate of the ensuing young during their existence in fresh water. Therefore, the program for this investigation in the future will include an intensive study and evaluation of the factors which influence the success of each year's spawning population and the mortality of the brood from the egg stage to the time it migrates to the sea.

CHIGNIK RIVER RED SALMON INVESTIGATION

The activities of this investigation during the past year were greatly reduced owing to the transfer of its personnel, Messrs. H. B. Holmes and G. B. Kelez, to other Bureau investigations.

A temporary assistant was stationed at Chignik from May until October for the purpose of collecting fish-scale samples and the observation of the commercial catches for marked fish. The data collected have been filed for future use.

BRISTOL BAY RED SALMON INVESTIGATION

Although funds were not available for a biologist to carry on field work in Bristol Bay during the past year, scales of the 1934 red salmon populations in this area were collected through the cooperation of the Alaska Division of the Bureau. Scale samples and body measurements of the red salmon which spawn in the Bristol Bay region have been accumulating for a number of years. Funds have been requested for the development of this important field of work, and it is hoped that they will become available in the near future.

PINK SALMON INVESTIGATION

The pink salmon are found in practically all the waters of Alaska but are most abundant in the southeastern section. Millions of pink salmon spawn in this section each season in its hundreds of streams which vary greatly both in size and character of habitat. The Bureau of Fisheries through its conservation policy, which was made possible by the White law, has been able to build up the pink-salmon populations of southeastern Alaska to a state where they are fluctuating near their maximum level of abundance. In fact, the commer-

cial catch of pink salmon in this section during the past season was the greatest in the history of the fishery. This, however, does not imply that these populations of salmon are no longer in need of constant observation for past experience has shown that they are subject to serious injury due to changes in both economic and natural conditions regardless of their state of abundance. Hence to secure information in regard to the changing status of these salmon populations which will lead to their conservation so as to provide for a permanent and productive fishery is the primary aim of the pink-salmon investigation.

The activities of this investigation in 1934, as in past years, were confined to a study of the pink-salmon populations in southeastern Alaska. Owing to the varied environmental conditions under which the pink salmon reproduce in this section of the Territory, it is believed that the fundamental facts secured from the study of its fishery may be applied generally to pink-salmon fisheries of Alaska. Dr. Frederick A. Davidson is in charge of the investigation, assisted by S. J. Hutchinson.

A paper on the homing instinct and age of maturity of the pink salmon was published during the past year. The evidence to date indicates that the pink salmon have a great desire to return to spawn in the streams from whence they came, but that some straying of the adults may occur in localities where a number of streams are in close proximity to each other. The evidence thus far collected also indicates that the pink salmon have a complete 2-year life cycle, that is, they invariably return to spawn at the close of their second year of life. The results from the racial analysis of the pink salmon which have been completed to date, substantiate the evidence in regard to the age of maturity of the pink salmon. These results indicate that 2 distinct salmon populations are found in the streams, 1 that spawns in the odd years and 1 that spawns in the even years.

A continuous study is being made of the yearly fluctuations in the abundance of the pink salmon in southeastern Alaska beginning with the inception of the industry in 1895. The results from this study show that wide fluctuations may be expected in the yearly abundance of these salmon. Since the pink salmon have a complete 2-year life cycle, the number that return to spawn any year is the result of a single spawning brood and not of several broods as in the case of the red salmon. Hence a marked change in the mortality of any brood is directly reflected in the number of salmon that return 2 years later. Knowing the disastrous effects that lack of rainfall during the spawning period can have upon the success of a spawning population, it is not surprsing to find these wide fluctuations in the yearly abundance of the pink salmon. The amount and time of occurrence of rainfall, however, are not the only factors which influence the mortality of the spawning salmon and subsequent brood. Hence a study is being made for the purpose of determining and evaluating all of the factors which influence the mortality of the salmon during their entire cycle of reproduction.

This study was started in the stream at Olive Cove, Alaska, but owing to handicaps encountered there it was transferred to the stream at Little Port Walter in the summer of 1934. The stream at Little Port Walter provides a very satisfactory location for this study.

It is only three-fourths mile in length, and the varied character of its stream bed provides for the study of practically all the types of spawning grounds found in the streams in southeastern Alaska. Furthermore, all of the commercial fishing which affects its salmon population is carried on just outside of the port and can readily be accounted for. Plans are being made for the construction of a permanent counting weir in the stream wherein both the adults that migrate into it to spawn and the resulting fry which migrate to the sea may be counted accurately. In this way both the mortality of the brood while in the streams and in the sea may be determined. It is hoped that funds will be available for a permanent observer at the stream for the purpose of making continuous observations of the environmental changes in the stream so as to determine the natural factors which influence the mortality of the brood. Once equipped with knowledge of the factors which influence the mortality of the broods, the Bureau will be able to develop further its conservation policy so as to provide for the most efficient utilization of the pink-salmon populations.

HERRING INVESTIGATION

With the exception of a few minor localities, the herring fisheries of Alaska may be grouped into four districts; namely, southeastern Alaska, Prince William Sound, Kodiak-Cook Inlet, and the Aleutian Islands. The fishery of southeastern Alaska is by far the most productive, and at the present time is supporting the majority of the fishing effort. Hence the activities of the herring investigation during the past year were confined mainly to a study of the fishery in this region. Dr. G. A. Rounsefell, who has been conducting the investigation since 1925, was transferred to the Puget Sound sockeye-salmon investigation in July owing to the need of a trained investigator for this work. E. H. Dahlgren, who has assisted Dr. Rounsefell for a number of years, was placed in charge of the investigation.

The stock of Alaska herring, being separated into a series of local races, presents a more complex problem than would be the case if it were a homogeneous population. The delineation of these races and a measure of the intermingling which takes place between stocks is of utmost importance. Estimates of changes in abundance and causes for such changes are dependent on this separation. Observations on the size and age compositions of the catch have clearly demonstrated the existence of dominant year classes, but the determination of the exact causes for such varying degrees of success of different spawning is yet to be solved.

A racial report now in press, by Dr. Rounsefell and Mr. Dahlgren, entitled " Races of Herring, *Clupea pallasii*, in southeastern Alaska ", presents the progress already attained in the problem of the segregation of populations. The results of an analysis of vertebral counts and of growth rates, the comparison of proportional representations of year classes, and the recovery of tagged herring are presented in this paper. The separation of the herring populations in the vicinity of Petersburg and Noyes Island, and the localities east of Clarence Strait and south of Sumner Strait, including Wrangell, was made evident by comparisons of the means of the vertebral counts. Size

frequencies of age classes show that the herring of Noyes Island, Douglas Island-Icy Strait area, Affleck Canal, and Peril Strait are much slower growing than those of other localities. Age distributions support the analysis of verbebrae and growth rates, in separating the populations of Noyes Island, Peril Strait, and the Douglas Island-Icy Strait areas from neighboring localities. The recovery at Cape Ommaney of tags affixed to spawners at Sitka demonstrated the relation between that spawning ground and the summer feeding area. The failure to recover any of the tags affixed at Cape Bendel in Frederick Sound gives negative evidence to show lack of intermingling of these fish at the feeding grounds in lower Cape Ommaney with the other populations.

Further experiments in the tracing of migrations by tagging were carried out during the spring of 1934. Twenty-one thousand five hundred and sixty-one metal belly tags were affixed to spawners at two of the major spawning areas, 8,394 at Craig on the outside of Prince of Wales Island, and 13,167 at Sitka, on Baranof Island. On 18,368 of these, a tag modified from those of previous years was used, the change consisting of having the tag stamped from steel, then plated with nickel, and in increasing the size to about double that of the nickel tags used previously. The larger size makes the tagging easier and faster. Corrosion, which might be expected to occur when there are imperfections in the plating, did not take place in the body cavity of the fish, and tags recovered 6 months after tagging showed their original luster. The 3,193 others were tagged with pure nickel tags left over from the 1933 experiment.

By means of the electromagnets installed at the reduction plants, 153, or 2.1 percent, of the steel tags affixed at Craig were recovered as against six-tenths of 1 percent of the nickel tags from the same experiment. Recoveries were made largely from the Warren and Noyes Island areas, although a small percentage were reported taken from Cape Ommaney. The Noyes Island and Warren Island fish are thus shown to be of the same population. Four hundred and eighty-eight, or 4.4 percent, of the Sitka steel tags and 40, or 1.8 percent, of the nickel tags at Sitka were recovered. They were taken, as were those of the 1933 experiment, from the vicinity of Cape Ommaney. A small fraction of these recoveries were made at the Warren-Noyes area. The degree of intermingling of the Cape Ommaney and Warren-Noyes Island populations, first indicated in this experiment, cannot be measured accurately until a device is perfected to extract the tagged individual before being run through the reduction plant. Such a unit has been devised and will be given a trial during the coming year.

Biweekly samples of the catch taken during the 1934 season in southeastern Alaska indicate a great predominance of 4-year-old individuals. As a result of the population being so young a relatively small pack of cured fish was prepared, a condition which may be expected to continue during the 1935 season. If this year class is not too seriously depleted, it should yield a good pack in 1936 due to the increased size of the herring.

Samples of the catch in Prince William Sound were collected, adding an additional year's data from this region. Sampling at Dutch

Harbor, carried on in previous years through the cooperation of the Alaska Division, was discontinued for lack of funds to analyze the data.

INVESTIGATION CONCERNING THE PROTECTION OF MIGRATORY FISH AT THE BONNEVILLE DAM

The future of the salmon, sea-run trout, and other anadromous fish of the Columbia River is endangered by the Bonneville Dam, which is being constructed by the War Department as a part of the Public Works program. This dam will obstruct the main Columbia below the tributaries that furnish the bulk of the spawning areas. The run of fish involved supply a great part of the sport fishing of the inland region of Oregon, Washington, and Idaho, as well as support a commercial fishery whose annual yield is valued at several million dollars. The task of designing fishways for the Bonneville Dam, therefore, becomes the most important undertaking of its kind ever attempted.

When the United States Army engineers started preparing detailed plans for the structures, they called upon the Bureau of Fisheries for recommendations relating to fishways. Such recommendations could not be furnished without a detailed study of the situation. In fact, the magnitude and importance of the task demanded consideration of new features in fishways. A portion of the funds allotted to the Bonneville project, therefore, was assigned to the Bureau of Fisheries for its investigations.

Harlan B. Holmes was placed in charge of the investigation. Henry F. Blood, a prominent engineer of Portland, Oreg., was employed to assist with the engineering phases. Other temporary employees have assisted with various biological and engineering phases of the work. The investigation has been conducted in close contact with the designing staff of the United States Army engineers, a committee representing the fishing interests, and the State fish and game departments.

The investigation has involved (1) an analysis of commercial fishery catch records and information from other sources for the purpose of estimating the time and magnitude of the runs of fish; (2) a familiarity with the physical features of the dam and power-house structures; (3) a historical study of the seasonal variations in the flow of the river, and the effects of these fluctuations upon the operation of fishways; (4) an extensive study of fishway principles including a survey of fishways now in use or previously tried, principles that have been proposed but never put into practice, and the development of new features; and (5) finally upon the basis of these investigations the presentations of detailed recommendations for fishway structures.

The investigation was started in November 1933, and some phases are not as yet completed. Tentative conclusions have been made available to the designing staff of the United States Army Engineers as rapidly as they become available. Formal recommendations for fishways for upstream migrants were submitted to the War Department in August 1934. Details and other features pertaining mainly to the passage of downstream migrants and the passage of fish dur-

ing the period of construction are being considered as rapidly as possible.

The fishways for upstream migrants recommended by the Bureau of Fisheries include 3 fish ladders, 5 fish locks, and 3 units of a new feature known as a "collecting system." The fish ladders are of special design to adapt them for wide ranges of variation in tailrace and forebay fluctuation. The fish lock, which is new in application to salmon and trout, embodies the essential principles of a navigation lock with minor differences to adapt it to the special use. The collecting system consists of a series of entrance weirs distributed at various points along the obstruction, all entrances communicating with a common passage which leads to the base of the fishway proper. The quantity of water flowing through the common passage is augmented by an auxiliary water supply, thus presenting as an attraction to the fish a much larger quantity of water than can be supplied by the fishway proper. The collection systems are recommended for use both with the fish locks and the fish ladders.

GREAT LAKES FISHERY INVESTIGATIONS

Owing to the continued curtailment of the Budget, no field work was conducted on the Great Lakes during the calendar year 1934. The Great Lakes research conducted under Dr. John Van Oosten was confined entirely to work in the laboratories furnished by the University of Michigan at Ann Arbor.

As in past years, the Bureau continued its cordial relations with the various Great Lakes States and provided them, whenever possible, with information and advice concerning their respective fisheries. Dr. Van Oosten represented the Bureau at various fisheries conferences on the Great Lakes as well as at the public hearing called by the National Recovery Administration at Muskegon, Mich., on April 25 to discuss the proposed Great Lakes fisheries code.

Much progress has also been made in what is often considered the more scientific aspect of fisheries research. The analysis of fisheries statistics begun on Lake Huron has been extended to Lake Michigan and Lake Erie. Life history studies of the whitefish, cisco, perch, yellow and blue pike-perch, and sauger of Lake Erie are nearing completion. It is planned to extend these important investigations to the other lakes of the Great Lakes chain.

FISHERY STATISTICS

The intensive statistical study of the commercial fisheries of the Great Lakes waters of the State of Michigan begun in 1933 was continued through 1934. Complete and detailed data are now available for the Lake Huron fisheries over the 5-year period, 1929–33. Similar statistical analyses have been started for the commercial fisheries of the Michigan waters of Lake Erie and Lake Michigan. In a brief preliminary publication, Dr. Ralph Hile and William R. Duden described the methods employed in these statistical investigations.

The statistical data on the commercial fisheries of Lake Huron have proved particularly valuable in their application to the problems relative to the use of the deep trap net for the capture of white-

fish. This new type of gear, which was introduced into Lake Huron in 1928, proved so very effective and its use expanded so rapidly during the succeeding years as to create grave fears concerning the future of the fishery. The Bureau's statistical data based on a study of the Lake Huron fisheries by geographical districts and over a period of 5 years, showed these fears to be well grounded. According to the Bureau's data, the history of the deep trap net fishery in a single fishing district may be described approximately as follows: The introduction of the deep trap net into a fishing area is followed by an immediate rise in whitefish production to a point far above the normal. This increased production continues over a period of 2 years, although a drop in the catch per unit effort may be detected in the second year of the use of the trap net. The third year sees a marked drop both in total production and in catch per unit effort.

The statistical evidence supplied by the Bureau that the use of the deep trap net occasions a rapid and severe depletion of the whitefish stock was directly instrumental in the securing of legislation regulating and restricting the use of this destructive gear. The publication of a complete report on the statistics of the commercial fisheries of Lake Huron is being delayed pending the analysis of the 1934 material.

PIKE-PERCHES

The racial and life history study of the three species of pike-perches (*Stizostedion*) of Lake Erie with which H. J. Deason has been occupied has progressed toward completion. Scale samples from 8,390 fish (2,812 yellow pike-perch, 3,441 blue pike-perch, and 2,137 saugers) have been mounted, aged, and measured during the course of the study. Lengths to the end of each year of life and annual increments of growth have been calculated and summarized in tabular form. Some conclusions of this work were given previously (Progress in Biological Inquiries, 1933), in which only a portion of the above material was employed.

Because of the necessity of correcting certain fundamental errors inherent in the application of the scale method of growth determinations to pike-perches, it was found desirable to devote some time to the basic assumptions of the scale theory insofar as they applied to these species of fish. This study dealt largely with the variations involved in the proportionate growth of the body of the fish and its scales. As a result of this study it was possible to secure more accurate data on the rate of growth of the various species.

The racial study of the pike-perches is concerned with the systematic relationship between the blue and yellow pike-perches, principally those of Lake Erie. A total of 1,038 preserved specimens have been examined and measured, which number is made up as follows: 449 blue pike-perch from Lake Erie, 52 blue pike-perch from Lake Ontario, 230 yellow pike-perch from Lake Erie, and 307 yellow pike-perch from Saginaw Bay in Lake Huron. The Lake Ontario and Lake Huron materials were employed in order to study the variation in a single species from different bodies of water. At the beginning of this study some 30 counts and measurements were made on each fish, but as the work progressed and it became increasingly evident

that some of the counts and measurements were valueless those proving not trenchant were dropped. Only 7 measurements and 2 counts (lateral line scales and number of vertebrae) were retained as indicative of possible racial differences.

Small average differences betwen the blue and yellow pike-perches of Lake Erie have been noted, but the percentage of overlap is great. Differences between the blue pike-perch of Lake Erie and those of Lake Ontario are as great as are the differences between the yellow pike-perch of Lake Erie and those of Lake Huron. In distinguishing the blue from the yellow pike-perch in Lake Erie the color and growth rate afford the best criteria. In Lake Erie these two species have a different distribution, constitute distinct fisheries units, and because of differences in growth rate and average size have different legal size limits. From the standpoint of law enforcement it would be most advantageous to have absolute morphological criteria which would differentiate the two species, but these apparently do not exist. Further work on the racial question must include the age determination of all specimens and a study of morphological variations with growth rate and with year classes.

YELLOW PERCH

F. W. Jobes continued the study of the life history of the yellow perch. Up to the present time scales of nearly 5,000 perch have been analyzed for age and growth rate. The perch material was exceptionally well adapted to an investigation of the growth relationship between the body of the fish and its scales. As a result of this work a better conception will be obtained concerning this most difficult problem that confronts nearly every investigator of the life history of fishes.

OTHER OUTSTANDING PROBLEMS

Although some of the most controversial of the practical problems on the Great Lakes, such as the proper mesh in trap nets and pound nets, destructiveness of chub nets to trout, regulation of deep trap nets, method of measuring mesh in gill nets, size limits of fish, and pollution, have been solved, much remains to be done. The controversial question of the destructiveness of hooks and bait nets to immature fish needs investigation. Further experimental work should be done on the proper mesh of gill nets employed in Lake Erie. A satisfactory method for measuring the mesh of heavy twine must be developed.

UNIFORM REGULATION AND DEPLETION

One of the most urgent needs on the Great Lakes today is concerted action by the various Commonwealths, both in this country and in Canada, to regulate and protect the commercial fisheries of the Great Lakes. Since 1927 the Bureau has cooperated with the various Commonwealths in some 10 interstate and international fisheries conferences. During this period the Bureau, in cooperation with various State conservation departments, has concentrated its scientific research on the Great Lakes on those controversial practical

problems that previously had prevented enactment of uniform regulation. In spite of the vast amount of scientifically collected data available to support the recommendations adopted at the conferences, little progress has been made in the enactment of the recommendations into laws.

The necessity of uniform regulation is obvious from the fact that, in many cases, fishermen from 2 States or 2 countries depend on the same population of fish. Lack of uniformity not only causes much unfair competition between fishermen of adjoining States but also fails completely to give the fish the necessary protection. Twelve species of fish have been either exterminated or seriously threatened. The blackfin bloater and salmon of Lake Ontario have been completely exterminated. The sturgeon, blackfin, chub, and Lake Erie cisco no longer support a commercial fishery. The other six species of chubs are severely depleted, and the whitefish is seriously threatened with commercial extinction. The final result of continued lack of uniform regulation appears to be obviously indicated by what has happened in the past.

OYSTER INVESTIGATIONS

The investigation of various problems relating to oyster culture was carried out in all of the principal centers of the oyster industry of the Atlantic and Pacific coastal States and the Gulf of Mexico. As compared with the previous year, the work was expanded by an experimental study of the oil-pollution problem in Louisiana waters in cooperation with the State Department of Conservation. Preliminary surveys made in 1933 clearly indicated the necessity of conducting a comprehensive investigation of this important problem.

The United States fisheries laboratories at Woods Hole, Mass., Beaufort, N. C., and Washington, D. C., served for laboratory investigations. The Bureau's field stations at Milford, Conn., and Olympia, Wash., were used as headquarters for field investigations and experiments on the cultivation of oysters. In both places the work was carried out in cooperation with the State authorities.

This work is being conducted under the supervision of Dr. Paul S. Galtsoff.

EXPERIMENTS ON OYSTER CULTURE

Experiments on oyster culture were continued by Dr. Galtsoff and V. L. Loosanoff at Milford, Conn., in cooperation with the Connecticut Shellfish Commission and the Connecticut Oyster Farms Co. During the summer the State's boat, the *Shellfish*, was used for field work in Long Island Sound, while during the cold season the research work was dependent upon the facilities offered by the Connecticut Oyster Farms Co. All of the laboratory work was carried out at the Osborn Zoological Laboratory, Yale University, and at the United States fisheries laboratory, Woods Hole, Mass. As in previous years, much needed information was supplied to the oystermen regarding the expected time of spawning and setting. On several occasions, at the request of the United States War Department, Mr. Loosanoff assisted in examining the oysters and oyster grounds in New Haven Harbor to determine the effect of the dredging opera-

tions conducted by the United States Corps of Engineers. On many occasions the oyster growers of the district called upon the laboratory at Milford for information and advice concerning various problems of oyster culture.

The major part of the work was a continuation of the investigation on the growth and fattening of oysters started by the Bureau in the spring of 1932. It consisted mainly of a study of environmental conditions and seasonal changes occurring in oysters. By comparing the temperatures of the water for the last 3 years, two points of great biological interest and significance become apparent: First, the duration of the hibernation period and the activity of the oysters vary, but within very narrow limits. During the years 1932, 1933, and 1934 the oysters hibernated 155, 160, and 149 days, respectively; second, the spawning period, that is, the number of days per year when the temperature of the water remained above 70° F., was 42 in 1932, 69 in 1933, and 59 in 1934. It is interesting to note that the shortest period of hibernation occurred in 1934 regardless of the temperature during this year. The spawning period of 1932 constituted only about 60 percent of that in 1933.

From the observations on phosphates it becomes evident that the utilization and regeneration of these nutrient salts in Long Island Sound is a definite cyclic process with a minimum amount present in the water during the warmest part of the year and a maximum amount occurring in winter. The temperature of the water and solar radiation are the two principal factors controlling the phosphate cycle, which in turn determines the fluctuations in the abundance of plankton. Analysis of river water showed that it is very poor in phosphates and contributes very little to the phosphate reserve of the Sound.

Observations on the growth of oysters show that they continue to increase in length and weight throughout the entire year, including the winter months. The rate of growth gradually decreases with age. In 1932 the average increase in length of 4-year-old oysters planted on experimental beds at Charles Island was about 2 cm, in 1933 it amounted to 0.9 cm, and during the last year it did not exceed 0.5 cm. Changes in the increase in total weight are even more striking. In 1932 the increase in total weight of 4-year-old oysters was 72 percent, in 1933 it was only 40 percent, and during the last year less than 10 percent. Thus, the self-inhibiting phase of growth—that is, the phase during which the rate of growth decreases with the increase in size or weight of the organism—is very pronounced in the 6-year-old oysters. The weight of the shells of oysters examined during the year constituted from 72.9 to 82.5 percent of total weight, the average, 77 percent, being almost identical with that obtained in 1932 and 1933.

During the year the weight of the meat constituted from 10 to 13 percent of total weight, the minimum occurring after spawning; that is, in August–September.

Observations on the glycogen and mineral content of the oysters were continued. Of the 199 samples of oyster meats collected during the course of the investigations 45 were analyzed for iron, copper, manganese, and zinc.

Observations on the spawning of oysters made by P. S. Galtsoff and J. F. Reppun at Woods Hole disclosed some interesting details of this process. It has been found that the eggs of an ovulating female pass through the gills and are discharged from the inhalent chamber instead of being expelled directly with the outgoing current of water passing through the cloaca. Because of this peculiar manner of shedding, the eggs are more uniformly distributed in the water and have a better chance to meet with the sperm. Experiments with artificial stimulation of spawning produced interesting results, showing that male oysters can be induced to shed sperm by a great variety of organic compounds, as, for instance, various hormones (thyrosin, theelin, two extracts of pituitary gland), sugars, peptone, egg albumen, sperm of various mollusks, and even yeast. The reaction of the female is, however, very specific; it can be induced only by the sperm of the oyster.

OIL-POLLUTION INVESTIGATIONS IN LOUISIANA

In an attempt to carry out a more comprehensive study of the oil-pollution problem in Louisiana, where a serious mortality of oysters occurred in 1932–33 coincident with the development of oil wells, the Bureau obtained from the Civil Works Administration an approval of a project to carry out both field and laboratory experiments in the affected territory. Unfortunately, out of the $42,000 allotted for this purpose only $3,000 were made available to the Bureau, and after the completion of a preliminary hydrographic survey of Timbalier and Terrebone Bays and adjacent bodies of water by R. O. Smith, the work in Louisiana was discontinued. Laboratory experiments were carried out, however, by H. F. Prytherch and R. O. Smith at Beaufort, N. C., and P. S. Galtsoff and V. Koehring at Woods Hole and Washington. Although the exact cause of the mortality of oysters had not been determined, the results of the laboratory experiments throw light on the possible effect of oil pollution on oysters. The report of this work has been submitted for publication.

The laboratory experiments were designed to test the effect of crude oil and oil-well bleed water on the vital activities of the oyster, especially on the rate of feeding, and on the growth of diatoms which constitute the principal food of the oyster. Using a method developed by Galtsoff in his previous studies on the physiology of feeding, hundreds of records were obtained showing the effect of the presence of oil on the rate of pumping of water through the gills. The results of these observations show that crude oil contains certain soluble in the sea water substances which inhibit the activity of the ciliated epithelium of the gills and reduce the amount of water which the oyster passes through the gills. This toxic effect is proportional to the concentration of the water soluble fraction of crude oil. It is of interest that repeated washing of one sample of oil seems to have no effect on toxicity of the extract, for samples of it obtained from oil that had been washed 28 times were as toxic as those prepared from a new sample. Oil extracts have no effect on the adductor muscle and oysters kept under oil or in running sea water which was allowed to pass through a layer of oil remain open for the same periods of time

as the controls. But the ciliary epithelium is very sensitive to the oil extract which inhibits its action. Since the oyster feeds on minute plants suspended in water, the rate of feeding is directly proportional to the volume of water pumped through the gills.

There is no doubt that the presence of oil decreases the rate of feeding of oysters, and oil absorbed by colloidal clay and deposited on mud bottom may exert its adverse effect on oysters long after all traces of it have disappeared from the surface of the water.

Oil-well bleed water has an effect on oysters similar to that of the oil extract.

Experiments with the diatom *Nitzchia dosteria*, grown under controlled laboratory conditions, show that the rate of propagation is decreased by oil floating on the surface of the experimental flask and by the addition of oil extract. From the results of the laboratory experiments an inference can be drawn that both factors, the decrease in the rate of feeding of oysters and the diminished production of diatoms, create conditions adverse to the cultivation of oysters in the oil-polluted areas.

BIOLOGY AND CULTIVATION OF HARD-SHELL CLAM (VENUS MERCENARIA)

While certain phases of the life history of *V. mercenaria* are quite well known, chiefly through the work of Kellogg and Belding, much is still left to be learned about this animal, and there is a growing demand for the information regarding the methods of its cultivation. The aim of the study being conducted by V. L. Loosanoff at Milford, Conn., is to obtain a broad knowledge of its life history, habits, and physiology, and to develop practical methods of propagation. It is expected that the results of this investigation will be instrumental in devising methods for increasing the natural supply and for the preservation of the clam fisheries.

At present, the study is confined to the following phases: Development and seasonal changes of gonads, spawning, development of the egg, growth, and feeding.

The work along the first line consists in histological and cytological studies of the material collected at regular intervals from the experimental clam beds near Milford, Conn. The study is not quite completed. It appears from the material examined so far that the primary gonads of young clams are of protandric nature, that is, the individuals first pass through the male phase. Whether the *Venus mercenaria* is strictly protandric or some of the individuals mature as females without the completion of a preliminary male phase will be established upon the examination of more material. Young clams 6 to 7 mm long already contain apparently functional spermatozoa.

Studies of the seasonal changes in the gonads of adult clams reveal processes which differ markedly from those observed in the oyster. In the latter, after spawning is completed the gonad tissue is absorbed, so that in the winter the gonads are in a well defined resting stage. In Venus, a certain amount of absorption is also evident, the principal degeneration of unspawned eggs taking place in December, but the gonad follicles do not shrink noticeably, and well developed ovocytes are always present. In the male the situa-

tion is still more amazing. Active spermatozoa are present in every month of the year. Upon being placed in the water they swim actively and behave in normal fashion. One interesting observation has been made on the movements of spermatozoa. During the study of fertilization it has been observed that sperms of different clams do not behave similarly. While they all exhibit spiral movements, the spermatozoa of about 75 percent of males move in circles in an anti-clockwise direction, while the other 25 percent of the males produce sperms moving in the opposite direction. The sperms of one male usually all move in the same direction. On several occasions young ovocytes were found present in adult males 6 to 8 years old. This apparently shows the potentiality for change of sex even in adult clams. However, gonads of truly bisexual character in an adult clam have been observed in one case only. Functional hermaphroditism has been observed only once.

A study of the spawning of clams and its physiology was conducted last summer. It has been found that it is very difficult to induce the spawning of clams, especially females, under the laboratory conditions. The critical spawning temperature is higher than that required for the oyster. Under the laboratory condition 25° C. was the minimum spawning temperature.

To study the growth of young clams three experimental beds representing different environmental conditions were established in different parts of Milford Harbor. Young clams from all of the beds were measured at regular intervals and the progress in growth recorded.

The feeding of clams depends upon the combined action of syphon, gill epithelium, and adductor muscles. At present only shell movements are being studied. The clams are kept under natural conditions in the large concrete tanks, 20 by 18 by 6 feet, in which the water is renewed by tidal action twice each day. Since the beginning of the experiment on October 17, 1934, over 160 records of shell movement have been obtained covering the range of temperature from 0° C. to 13° C.

A study of the glycogen content of hard-shell clams was begun last March. Samples of clams were collected every 2 weeks and the meats analyzed. The glycogen content varies greatly with physiological changes occurring in the clams at different seasons of the year. The maximum quantities of glycogen found in clams during the prespawning period constituted 10 to 11 percent of the meat weight (fresh basis). After spawning a very sharp drop takes place until at times it equals only 3.3 percent of the meat weight. Gradual recovery takes place after that and during the winter the glycogen content of the clams constitutes 6 to 9 percent of total weight. Grown under similar conditions clams always have a higher glycogen content than the oysters.

REHABILITATION OF PUBLIC OYSTER BEDS IN NORTH CAROLINA

In order to restock the depleted natural oyster beds of North Carolina, extensive operations for the transplantation of seed oysters have been carried out under the direction of Dr. H. F. Prytherch,

in cooperation with the North Carolina Department of Conservation and the Federal Emergency Relief Administration.

Over 825,000 bushels of seed oysters at an average cost of approximately 8 cents per bushel have been planted, and 78,567 bushels of old oyster shells have been scattered over the bottoms to provide a place of attachment for subsequent generations of this shellfish. Inspection of the replanted beds in Pamlico Sound during September 1934 showed that a high percentage of the seed oysters have survived transplanting and culling operations and, because of their rapid growth under more favorable conditions, would provide good market stock in approximately 2 years. At the recommendation of the Bureau all replanted areas have been closed by a recent ruling of the State Fisheries Board for a period of 2 years in order to enable the transplanted oysters to reach market size.

INVESTIGATION OF OYSTERS AT NEW RIVER, N. C.

A general survey was made during March by Dr. H. F. Prytherch of the oyster beds in the New River region to determine the cause of the poor condition of oysters during the previous winter. The results of the Bureau's investigation, briefly summarized, are as follows: (1) The poor condition of New River oysters is attributed to exceptionally dry weather and decreased river discharge during the period from October 1933 to February 1934 when precipitation was 75 percent below normal; (2) closure of the inlet has not interfered with oyster growth and reproduction, as sufficient salt water now passes into this region through two larger inlets via the Inside Route Canal; and (3) deepening of New River Inlet is not advisable as it might easily increase the salinity of the water to such an extent that oyster beds now producing a high-grade product would be overcrowded with seed oysters and also subject to severe attacks by the boring sponge.

OYSTER INVESTIGATIONS IN FLORIDA

A complete survey of the principal oyster-producing areas in northwest Florida was conducted by Dr. H. F. Prytherch in cooperation with the State Department of Conservation and Federal Emergency Relief Administration for the purpose of restoring and developing this natural resource as a work-relief project. The most important beds were found to be in a depleted condition and in need of restocking with seed oysters and shells. Experimental planting operations of the type successfully carried out by the Bureau in this region last year clearly demonstrate the advisability of employing such methods on a large scale. Biological studies were made of the spawning and setting of oysters in these waters, which show that the planting of old shells should be carried out during the period from April 1 to September 15.

In Choctawhatchee Bay over 12,000 barrels of shell have been distributed over barren bottoms to create new beds and to increase the acreage of areas which are producing high-grade oysters. The general procedure is to plant 100 to 300 barrels of shell per acre, over

which seed and adult oysters from the inshore reefs will be distributed in the spring to serve as spawners.

Destruction of oysters by parasitic flatworm.—A parasitic natural enemy of the oyster known as the " wafer " or so-called " leech " has become a serious menace to the continued natural production and private cultivation of this shellfish in Apalachicola Bay, Fla. Investigations conducted by Dr. Herbert F. Prytherch, in cooperation with the Florida Department of Conservation, show that this pest in the last 3 years has completely destroyed the seed and adult oysters on several of the best natural beds and is spreading rapidly to other valuable areas. The parasite is a turbellarian flatworm, *Stylochus inimicus*, measuring from one-half to three-fourths inch in diameter, which enters the shell of the oyster and feeds gradually upon the meat until it has killed its host. Since the fall of 1932 the parasite has destroyed the oysters on five natural beds comprising an area of 800 acres on which a crop estimated at 350,000 bushels, having an approximate value of $175,000, has been lost. Recently this natural enemy has spread to other beds at a distance of 12 miles from the original outbreak and to a nearby oyster reef, which is the largest in this region and contains nearly half of the entire crop. The Bureau's investigations show that the rapid growth, reproduction, and spread of the leech in Apalachicola Bay is associated with an unusually dry period, a considerable decrease in river discharge, and an increase in the salinity of the coastal water of this region. It is desirable that extensive dredging operations be undertaken to destroy the leech on its principal breeding areas and that scientific studies be made of this parasite, which has been recently found on oyster beds from North Carolina to Texas.

PROTOZOAN PARASITE OF VIRGINIA AND LOUISIANA OYSTERS

Oyster planters in Mobjack Bay, Va., and in Terrebonne Parish, La., suffered a loss of their stock amounting to over a million dollars during the winters of 1929–30 and 1932–33, respectively. Cytological studies of oysters from both regions conducted by Dr. H. F. Prytherch show that they were heavily infested with a parasitic protozoan, which tentatively has been identified as one of the Haplosporidia. This parasite was particularly abundant in the tissue of the adductor muscle, mantle, and gills, and was frequently found in the muscle of the heart. Representative samples of oysters from the mortality areas showed in every case a heavy concentration of this protozoan, the number ranging from approximately 50 thousand to 1 and 2 million per oyster.

In the immediate vicinity of the fisheries laboratory at Beaufort, N. C., it has been observed for several years that a large number of oysters die at an age of 1½ to 2 years, following a period of abnormal shell growth, similar to that observed in the oyster mortalities in Virginia and Louisiana. Recent cytological studies have shown that these oysters are also heavily infected with the same protozoan parasite. In all three localities the mortality was highest in oysters grown under crowded conditions in which large numbers of this minute parasite were found. From a practical standpoint it is apparent that oysters should be planted sparsely to prevent reinfection and spread

of the parasite and also allow more favorable growing conditions for those which are heavily infected. Investigations are being continued at the Beaufort laboratory for the purpose of determining the life cycle, method of distribution, and proper identification of this microorganism which appears to be a new natural enemy of the oyster of considerable economic importance.

OYSTER INVESTIGATIONS IN WASHINGTON

For a number of years the Olympia oyster industry has had difficulties due to unsatisfactory catches of seed oysters. Although the quality of the product has been normal the growers were unable, by use of the usual methods, to collect spat enough to fill the beds. For this reason an investigation of the spawning and setting habits of this species of oyster was undertaken by Dr. A. E. Hopkins. During four seasons accurate data have been collected on various phases of the problem, and the cumulative results are becoming constantly more significant. In addition, the rapid expansion of the Japanese, or "Pacific", oyster industry has involved numerous problems, such as propagation of this species in American waters, effect of environmental factors on fattening, and so forth.

Experimental studies have been carried on in typical oyster-growing areas of the most important bays near Olympia. Three times weekly during the breeding season 100 adult oysters (*Ostrea lurida*) were opened on each of the test beds, and the larvae from gravid specimens preserved for laboratory study. In this manner it was learned that larvae develop for about 10 days in the maternal brood chamber before being cast out into the open water. The data also show accurately the time and intensity of spawning in each locality throughout the season, as well as the total amount of spawning taking place. For example, in Oyster Bay in 1932 all of the oysters produced larvae once and 75 percent of them produced second broods. In 1933 only about 75 percent spawned as females, and in 1934 between 90 percent and 100 percent did so. These results indicate that there is wide variation between different seasons in the number of times spawning occurs, and consequently in the potential seed catch.

The time of beginning of spawning is clearly determined by temperature. During each season the first gravid specimens were found when the average daily water temperature reached 13° to 14° C. Records for the past 3 years show that the interval between spawning and setting varied between 39 and 51 days, of which the first 10 days represent development within the maternal brood chamber.

By careful analysis of the time and intensity of setting throughout the season it has been found that in certain bays periods of setting occur at intervals and are associated with the tidal cycles. This was found during previous years, and the 1934 results furnish further confirmation. Attempts have been made to determine in what manner the tidal cycle is effective, but the problem requires further experimentation. Although setting is heaviest during a run of extreme low tides, actual attachment of the larvae does not occur when the tide is low but appears to take place primarily at relatively high tide. Whether copper in the water is the effective agent for this species has not yet been determined.

Although at present it is impossible to predict with certainty when setting will begin, it is known that after the first larvae begin to attach there is still sufficient time for the growers to plant cultch before the most profuse setting takes place. By making constant observations and determining the exact date when setting begins one may be reasonably certain when the peak of the set will arrive, since this is so closely associated with the tidal cycle. By this method in 1933 and 1934 definite advice was given to oyster growers as to the time to plant cultch for best results. The seed catch of those who followed the advice has amply demonstrated the adequacy of the method.

Several years ago, on the basis of observations that larvae attach most abundantly to lower surfaces, a type of cement-coated cardboard spat collector—a modification of the egg-crate filler—was designed to furnish a large amount of horizontal surface. These collectors are now being used commercially in Puget Sound with very satisfactory results.

That the circulatory system of the oyster is more complicated than previously thought was shown by the discovery that an oyster possesses a pair of accessory hearts, or large, rhythmically pulsating blood vessels, within the mantle walls of the cloacal chamber. They appear to pump blood from the kidneys to the mantle and gills, where it is aerated. It is suggested that the organs are homologous to the branchial hearts of cephalopod mollusks. The accessory hearts are found in all three commercial species of oysters in the United States.

Further experiments were made on the adaptation of the Pacific oyster to changes in salinity. Adaptation of the feeding mechanism is relatively slow following a lowering of salinity, but rapid after a rise. Feeding ceases completely when salinity is reduced to 12–14 parts per thousand, and apparently adaptation does not occur, although growth of shell continues. It is probable that adaptation to salinities of 15–20 parts per thousand is never such as to permit the oyster to feed as rapidly as it does at 25–35 parts per thousand.

INVESTIGATIONS ON AQUICULTURE

Investigations in aquiculture were conducted in 1934 under the direction of Dr. H. S. Davis. These investigations, which were originally undertaken in connection with fish-cultural operations in the hatcheries, have been expanded to include field studies dealing with the various factors which affect fish in their natural environment. Opportunities for such field investigations have been greatly increased during the past year as a result of an allotment from the Public Works Administration for stream surveys and stream improvement in the national forests and parks.

The experimental hatcheries at Leetown, W. Va., and Pittsford, Vt., are strategically located for conducting investigations in the waters of the national forests. The Leetown station is within a short driving distance of both the George Washington and Monongahela National Forests, while the Pittsford station is situated within the boundaries of the recently enlarged Green Mountain National Forest.

Thus, both stations afford exceptionally favorable opportunities for conducting field studies and experiments in cooperation with the United States Forest Service.

POND-FISH CULTURE

Investigations in pond-fish culture during 1934 were limited to those conducted by O. Lloyd Meehean at the Natchitoches (La.) station. These investigations are designed primarily to throw light on problems which have arisen in connection with pond culture in the Southern States where conditions in many respects are quite different from those found at hatcheries in the North.

The investigations at the Natchitoches station were concerned chiefly with the use of fertilizers in pond culture. Since experiments in previous years have shown conclusively that proper fertilization of rearing ponds results in a marked increase in the production of fish, the experiments during 1934 were designed primarily to furnish a comparison of the value of different fertilizers for this purpose. The results, however, are inconclusive, since no correlations were found between any of the ecological groups of food organisms and the amount of the different elements composing the fertilizers. It is concluded that this was due to the fact that more fertilizer was used than was necessary. Consequently, there was at all times a surplus of food material available. Under such circumstances it is logical to assume that the production would be limited by other factors than food.

The results agree with those obtained in 1933 in failing to show that there is necessarily any correlation between the production of plankton in a pond and the production of fish as claimed by some authors. There is, however, a distinct correlation between the number of Chironomidal larvae per unit area of bottom sample and the production of fish. This indicates that fish production is dependent on bottom organisms rather than on plankton.

The experiments indicate that the number of fish produced per acre is not a good index of production in a pond after bass have reached a length of about 2½ inches. The greater forage area needed by the larger fish and the change in food habits necessarily reduces the number of individuals. Consequently, with larger fish the weight of the fish rather than numbers should be taken as a criterion of production. This is especially important in the South owing to the early spawning season, the young bass usually reaching a length of 2½ inches by the 1st of June. Bass can be reared successfully to this size without the use of forage minnows, but if they are to be kept in rearing ponds through the summer the need of forage fish is clearly indicated.

As a result of these experiments, Mr. Meehean believes that in the Gulf States at least it may be necessary to choose between heavily fertilized ponds which will carry a large number of bass to 2 or 2½ inches and ponds producing an adequate supply of forage food for a longer growing season. In the heavily fertilized ponds the number of fish may run very high if the ponds are drained and the fish removed by the 1st of June. These ponds could be utilized during the remainder of the season for sunfish and catfish or other species that require a longer growing season and spawn later. The other alterna-

tive will be to supply a large amount of forage food to carry the bass through the summer until October or November, in which case there will be a smaller number of large bass.

An allotment from the Public Works Administration has made possible the construction of a number of bass ponds at the Leetown (W. Va.) experimental station, but these ponds were not completed in time to be used during the season of 1934.

TROUT CULTURE

Feeding experiments.—Owing to lack of sufficient funds the feeding experiments which have been carried on at the Pittsford and Leetown stations for several years were discontinued. However, at the Leetown station some preliminary studies were made on the growth of yearling and 2-year-old trout. These fish were fed a diet composed of 60 percent sheep liver, 20 percent salmon egg meal, and 20 percent meat meal. Each experimental lot consisting of 325 fish was held in a circular pool 22 feet in diameter. It was found that the rate of growth of both yearling brook and rainbow trout as well as that of 2-year-old rainbow and brown trout was considerably smaller than in the case of fingerlings. In feeding fingerlings the amount of food consumed increases steadily throughout the summer; but with the older fish on the diet used, the amount consumed remained unchanged in some instances for 2 months or more, the fish continuing to grow nevertheless.

It was found that both yearling brook and rainbow trout consumed a greater amount of food per day in proportion to their body weight than the 2-year-old fish. The experiment also showed that rainbow and brown trout could eat more of the diet fed without ill effects than the brook trout. In other words, the brook trout, when given an opportunity to eat all they could, suffered injurious effects as indicated by high mortality and loss of appetite. This indicates that brook trout are more easily overfed than brown or rainbow trout.

The nutrition studies have been continued at the Cortland, N. Y., hatchery by Dr. C. M. McCay and A. V. Tunison. Two lines of research were conducted during the past year: (1) Studies of the interrelationship between various foodstuffs, rate of growth, and mortality were continued; and (2) chemical-balance studies with trout have been initiated. The chemical-balance studies depend upon accurate chemical analyses of both the food ingested and the excreta.

The experiment to determine the relative ability of lake trout (*Cristivomer namaycush*), brown trout (*Salmo fario*), rainbow trout (*Salmo irideus*), and brook trout (*Salvelinus fontinalis*) to convert foodstuffs into body tissue were carried through the ninety-second week. All four species were maintained under similar conditions and fed the same diet, which consisted of 2 parts fresh beef liver and 1 part dry skim milk. The number of individuals was reduced from time to time so as to prevent overcrowding. The uniformity of the growth rates of the four species is surprizing. Over long periods of time the growth tends to be strictly logarithmic. However, the rate changed to a lower one after the thirty-second

week. Under the conditions of the experiment the lake trout were the most efficient in converting food into body tissue, while the brown trout were the least efficient. It is evident that older fish are more efficient in the conversion of their food. The rate of growth and the maintenance requirements partly tend to counterbalance each other in the efficiency of food conversion.

Experimental feeding of trout fry has given some interesting results, from which the following conclusions can be drawn: (1) A mixture of 2 parts fresh beef liver and 1 part dry skim milk is a satisfactory diet for fry; (2) a higher percentage of milk tends to increase the mortality; (3) the mechanical method of feeding makes no difference in results when the fry are fed the same amount in percent of body weight; (4) different groups of fry yield uniform data for food conversion when the same diets are employed; (5) on a dry-food basis, the conversion of liver and milk is more efficient and economical than liver alone; (6) the most efficient conversion of food occurred in one of the groups of brook trout kept in warmer water; and (7) increasing the daily feedings from 4 to 6 gave a slightly better growth and conversion.

The large-scale experiments in the practical feeding of dry-feed mixtures of cottonseed meal, fish meal, dry skim milk, and salmon-egg meal supplemented with raw liver were continued. A different strain of fish was used in 1934 as well as several improvements in methods, but the results were practically the same as those obtained in 1933.

An attempt was made to produce the same brilliant coloration found in wild trout. Dried salmon eggs were extracted with 95 percent alcohol and the colored extract fed to brook trout. The fish fed the extract developed marked color at about the eighth week, while those fed the residue developed little, if any, color. Salmon oil produced a similar coloration when mixed with the dry food at a 10 percent level. However, in no case did the colors produced approach those of wild fish. The fat soluble histological pigments Sudan (III and IV) failed to produce color in the trout except that when fed at the 0.5 percent level the intestines and mesentery fat showed some pigment.

Some further work has been done on the feeding of preserved fresh meat. Liver preserved in both 1 and 2 percent formalin and in chlorinated lime was sealed in glass jars and kept at 10° C. for 2 years. This preserved liver was then used at a 25 percent level, to supplement a mixture of skim milk, fish meal, and cottonseed meal. After 14 weeks the trout had doubled their weight with no signs of being poisoned by the preserved meat.

The chemical balance studies have concerned themselves with the determination of the digestibility of fats. Two objectives were in mind: (1) to determine whether oils such as cottonseed and salmon were digested better by trout than a hard fat such as hydrogenated cottonseed oil (Crisco), and (2) to measure the relative digestibility of these fats by trout of two different ages and sizes. It was found that the oils were digested better than the solid fat, and that there was no real difference between the digestion and utilization of cottonseed oil and salmon oil. The melting point of the oil or fat is the essential characteristic rather than its origin. The trout seemed to utilize

about the same percent of the fats when the level in the diet was 7 and 25 percent. Fats were digested to about the same extent by trout weighing 2 grams and those weighing 100 grams.

Selective breeding.—Experiments in selective breeding of brook trout were conducted at the Pittsford (Vt.) station under the direction of R. F. Lord. At the beginning of the year, 43 lots of fingerling trout were being held in small compartments in hatchery troughs. Each lot was composed of the progeny of a single pair of selected fish. The parent fish were in their third year and averaged 12.9 inches in length with an average weight of 16.6 ounces in the case of the females, while the average weight of the males was 18.2 ounces and the length 13.6 inches. Such differences in the sizes of male and female brook trout of the same age are quite typical.

The young fish were kept under strict observation, and late in the spring those lots which did not reach the desired standard were discarded. The remaining lots were reduced to 400 fish each, which were kept segregated during the summer. The surplus fish from these lots were retained for general brood stock.

At the close of the season the various lots were carefully compared and only the very best lots with regard to growth, resistance to disease, and hereditary background were retained.

As indicated in previous reports, the results of these experiments in selective breeding have been very gratifying. There has been a remarkable increase in the egg production and rate of growth of selected fish and also an improvement in resistance to disease. Similar experiments with rainbow and brown trout are being carried on at the Leetown station, but there has not yet been time for these experiments to show material results.

Experiments in rearing exotic species.—The Pittsford brood stock of Montana grayling was stripped for the third time in the spring of 1934. A good hatch was obtained from these eggs, and about 6,000 fingerlings were retained for wintering. It is planned to use these fish to stock a pond which has recently been built in the Green Mountain National Forest. A stock of grayling derived from eggs shipped from Pittsford is also being reared at the Leetown station. These fish have done very well, and it is expected they will produce eggs in the spring of 1936.

Excellent results were obtained from a small lot of golden trout (*Salvelinus aureolus*) eggs from Lake Sunapee, N. H., which were shipped to Pittsford in the fall of 1933. The fingerlings were carried through the summer with very little loss and by fall many of them had reached a length of 6 inches or more. A tendency of the fish to crowd together at one end of the trough was overcome by excluding the light.

A stock of California golden trout (*Salmo aqua-bonita*) is also being reared at the Pittsford station. These fish are quite susceptible to furunculosis, and considerable losses have occurred from this disease; but in other respects they appear to be no more difficult to rear than other species of trout.

Field studies.—An investigation of the results of planting a certain number of rainbow trout fingerlings in a 1-mile section of a spring-fed stream near Leesburg, Va., was continued by E. W. Surber, in charge of the Leetown station. In addition to collecting data on the

ages, condition factors, and food of legal size rainbow trout removed from the stream, quantitative studies were made of the natural food present. For this purpose bottom samples were taken in the gravel riffles at 10 to 16 stations along the stream at monthly intervals.

During the season of 1934, a total of 94 legal-size fish were taken from the stream with hook and line. This is a production of 27.66 pounds of trout per acre. These results agree very closely with those obtained in 1933, when a production of approximately 30 pounds per acre was recorded. Measurements of the fish showed that they had made a very good growth and were in excellent condition.

Food studies again demonstrated the great dependence of rainbow trout on terrestrial insects during the summer periods, but these studies also showed greater dependence on aquatic forms than in the previous season. A total of 196 bottom samples on gravel riffles showed an average wet weight of 5.047 grams per square foot and 0.982 gram dry weight per square foot for the year. This amounted to an average standing crop of 485.8 pounds (wet weight) per acre in the gravel riffles of the stream. A study of the variability of sampling showed that the samples varied less than one-third from place to place in the numbers of gammarus and fasciatus (the predominant organisms) in individual samples during May, June, and July.

An attempt to obtain statistics on the number of trout caught during the season of 1934 in several streams in Vermont through cooperation with the anglers was far from successful. Mail boxes painted a brilliant red to attract attention were placed along the streams at locations where anglers usually left their cars. A conspicuous sign attached to each mail box called attention to the fact that the Bureau of Fisheries was attempting to secure figures on the number of fish taken annually from the stream in question as a guide to future stocking. The anglers were urged to cooperate by giving the desired information on cards provided for the purpose, which were to be deposited in the mail boxes. The boxes were all in position when the fishing season opened on May 1, 1934.

In spite of efforts to secure the cooperation of anglers with the least possible trouble on their part, the results were very disappointing. Only a small percentage of those fishing in the streams filled out reports during the first day or two of the season, and as the season progressed the number of cards deposited in the boxes steadily decreased until toward the end of the season almost no reports were received.

The best returns were received from the anglers on Furnace Brook, although it was evident that only a small percentage of those fishing the stream filed the reports. The data revealed that during the months of May and June fishing conditions were quite uniform, with an average catch of 7.4 trout per fishing attempt. In July fewer anglers reported that the average catch was 13 trout. This is not taken to mean that fishing conditions had improved but that only the more successful anglers reported.

Similar returns were obtained on the South Branch of Cold River, a small mountain stream with an average volume of about 12 to 15 cubic feet per second. This stream was stocked with 700 marked

yearling rainbow in September 1933. Only 24 reports were received from anglers for the month of May, and these reported 82 rainbows of the 1933 planting. Three reports were received later, which brought the total number of rainbows caught during the season to 87 fish. This is a return of approximately 12 percent. Since it was evident that only a small percentage of the anglers reported their catch, it is believed that the returns from this planting were quite satisfactory. One rainbow was reported which had been planted in 1932. These experiments are being repeated during the present season.

In cooperation with the Middlebury College an attempt was made to obtain similar data on waters stocked and controlled by the college. Special permits required of those fishing in streams on college property were issued with the understanding that each angler would report his daily catch in a space reserved for this purpose on the permit. Even under these circumstances it was found very difficult to get returns, and the reports received were too meager to throw much light on trout-stream production. They do show, however, that the average daily catch of legal-size fish was 9.4 per trip in 1933 and 7.4 per trip in 1934. The reports also show that the number of short trout taken and returned to the stream greatly exceed the number of those which had reached legal size.

California trout investigations.—Work has progressed rapidly on most of the projects initiated in 1932 when these investigations were started. Subsequent experience necessitated several modifications of the original program and the work now consists of two major projects, the Hot Creek brood stock experiment and the coastal stream steelhead studies. The former project is under the direction of Dr. P. R. Needham, who is also in charge of the field program as a whole. The latter project is under the supervision of A. C. Taft. Work on several minor projects is being carried on as time permits. Three assistants are supplied to the work by the California Division of Fish and Game.

The Hot Creek experimental project was greatly expanded this year with the construction of a series of 12 concrete raceways, 20 feet long by 4 feet wide. Two new ponds to hold brood stock were also constructed as well as a combination garage, meat house, and laboratory. Late in the fall a small experimental hatchery was completed with C. C. C. labor. Over $3,000 was expended on these improvements. Over 67,000 small trout, consisting of 6 separate strains of rainbows and 1 lot of eastern brook trout, were placed in the ponds after construction work was completed. These fish are to form nuclei for rearing select domestic brood stocks for experimental purposes. An additional source of rainbow eggs is needed in California, and breeding experiments for high egg yields, rapid growth, coloration, and other genetically desirable characteristics, therefore, will be carried on largely with this species. One distinct advantage offered at the Hot Creek area is the tremendous natural production of shrimp, making it unnecessary to feed artificial food to many of the younger fish, thus reducing costs materially. Over a quarter of a pound of pure shrimp were taken from an area of 1 square foot in the watercress in one of the ponds. A fine series of springs supply about 30 second-feet of water at temperatures varying from 57° F. to 68° F. which permit rapid growth over most of the year.

Data from the coastal stream steelhead studies started in 1931 at Scott and Waddell Creeks and on the Klamath River are rapidly being augmented. The counting weir constructed on Waddell Creek in 1933 has been operated continuously since this time.

During the winter season of 1933–34 at Waddell Creek, the spawning migration consisted of 478 steelhead and 538 silver salmon of which 263 and 213 were females, respectively. The silver salmon migration was largely confined to the last 2 weeks of December, while the steelhead came in over a longer period which extended from January to the end of March. There was a considerable loss among the steelhead due to disease, which was probably furunculosis and which was associated with very low and warm water during March, April, and May. Most of these fish died after spawning. In addition to the adults moving upstream, 128 young fish varying in length from 90 to 295 centimeters were taken in the upstream trap during the months of December and January. These were undoubtedly fish which had spent the summer in the closed lagoon, and some of the larger were sexually mature males. They were given a distinctive mark and passed on upstream. Later, 70 of these fish were taken on their downstream migration with the other young steelhead.

There were small numbers of downstream migrating steelhead during December, January, and February, but the movement was greatest during March and April, and from length frequencies it appears that fish that had just completed their second year predominated. A total of 3,117 young steelhead were trapped and 2,452 of them marked by the removal of the adipose and right pectoral fins. During June, July, and August, a few fish of the year were taken in the trap each week.

The downstream migration of young silver salmon (*O. kisutch*) was much more concentrated than that of the young steelhead; that is, there was no scattering of fish previous and subsequent to the main movement. The migration was also later, coming in April and May. A total of 3,430 young salmon were taken, and 3,211 of them were marked by the removal of the adipose and right pectoral fins.

An interesting discovery was the fact that the two species of cottoids inhabiting the stream (*Cottus asper* and *C. gulosus*), apparently migrate downstream to spawn. During the period December to May, 3,357 of these fish were taken in the downstream trap and both males and females were approaching spawning condition as evidenced by the gonads. Although efforts were made to determine just where they spawned, neither eggs nor fry were found. These cottoids are very destructive to young trout and salmon and this annual period of migration may offer an opportunity to reduce their numbers in such streams as it is felt desirable to do so.

Work has been continued at Scott Creek on certain phases of the artificial propagation of steelhead and, in conjunction with Waddell Creek, on the homing instinct in these fish. The mouths of these two streams are separated by only 5 miles of coastline and the annual release of marked fish in each stream should make it possible to determine the degree of straying. It is becoming increasingly difficult to secure a supply of steelhead eggs for the hatcheries without encroaching on streams which are also heavily fished. An attempt is being made at Scott Creek to build up this stream for egg taking and

although water conditions have been so unfavorable during the past few years that parts of the stream have dried up completely, the run is being slowly increased through holding fish in ponds and planting them during the winter months. During the past year 10,054 of the fish planted were marked by the removal of both ventral fins. During the winter season 455 adult fish were taken in the trap and before release were tagged with celluloid disks and nickel wire. The tags were placed in the anterior base of the dorsal fin. Of the fish tagged the previous year approximately 7 percent returned this year as compared with a return of 13 percent from the previous year's tagging. The returns are quite obviously dependent on the age of the fish tagged as very few fish return to spawn the third time.

On the Klamath River 45,700 yearling trout were marked and planted during May. Part of these fish were from eggs taken in the Klamath River while 9,770 were from a possibly nonmigratory type of rainbow taken in Kosk Creek, a tributary of the Pit River. At Beaver Creek on the Klamath, arrangements have been made to install a trap at the egg-taking station to take downstream migrants. This will make it possible to correlate information obtained at Waddell Creek with that of the streams tributary to the Klamath.

Work was also continued on two minor projects, the Angora Lake and Truckee River marking experiments.

The Angora Lake project was started in 1933 with a plant of over 5,000 marked eastern brook trout. The objects of this experiment are to determine: (1) Total annual production in pounds of fish per acre of water as shown by anglers' catches; (2) survival rates from plants of various lots of marked trout of given sizes; and (3) the correlation between the actual production in fish and food conditions in the lake. The lake offers exceptional opportunities for obtaining complete returns from anglers, and the resort owner on the lake is receiving a small annual stipend to record and weigh all fish caught.

Returns for the fishing season of 1934 show that anglers took only 81 trout, having a total weight of 71.2 pounds. Since Angora Lake is, roughly, of about 5 acres area, these figures show that production in terms of fish landed by anglers was approximately 14 pounds per acre of water surface. The average catch per angler was 2.3 fish. Of species, 25 loch leven, 14 rainbow and 42 eastern brook trout were taken. The figures are based upon partially complete returns. None of the marked eastern brook trout planted in the previous summer entered the catches this year, due doubtless to the fact that their average size at planting was slightly under 2 inches.

Excellent returns have likewise been obtained from the Truckee River marking experiment which was started in 1932 with the planting of 40,000 trout. In 1933 an additional 40,000 were planted, and they entered into the catch in considerable numbers during the past summer. In one lot of 62 fish taken by anglers, 49 were fish of this marking.

Field studies of stream food problems were continued in Waddell Creek in the spring. though lack of time and the pressure of other matters prevented detailed work of the type carried on the year previously. Bottom food samples were taken to determine the bulk or weight of food which each group contributes to the total potential supply in this stream. It was found that caddisfly larvae and pupae,

which formed only 22.2 percent of the total number of organisms taken in one series of 13 samples, formed 43.9 percent of the total wet weight of all organisms, offering the most food by bulk of any group of aquatics. Mayfly nymphs, on the other hand, were most abundant, forming over 55 percent by number but only 28 percent by weight. Stonefly nymphs were third in weight of food at 12.2 percent and fourth in numbers at 7.8 percent. Aquatic truefly larvae and pupae (Diptera) formed 10.3 percent by number and only 7.9 percent by weight of total available foods.

Some work was started on the distribution and abundance of stream foods in relation to water temperatures and other ecological factors, but much further field and laboratory work will be necessary before results can be submitted on these phases of the problem.

FISH DISEASES

Investigations were conducted by Dr. Frederic F. Fish on the "ulcer disease" of trout which he has shown to differ in many respects from furunculosis with which it was formerly confused. The disease is characterized by definite thickening of the epithelium over a small area, producing an inconspicuous white patch which in general appearance closely resembles a small growth of fungus (sapolignia). This condition is best described as an "epithelial tuft." Eventually the skin becomes perforated and the small ulcer is formed. When a lesion of the "ulcer disease" develops on a fin, the soft tissue between the fin rays is destroyed leaving the rays projecting beyond the neucrotic tissue. As the disease progresses the neucrotic area advances in a more or less horizontal line toward the base of the fin. In advanced stages of the disease the fin may be entirely destroyed while the infection penetrates deep into the underlying tissue. There is no evidence, however, that the infection ever reaches the internal organs.

The causative agent of the disease is evidently a bacterium. Several species of bacteria have been isolated from diseased fish, but it has not yet been possible to demonstrate conclusively that any one of them is the specific etiological agent.

During the early part of the year Dr. Fish was stationed at the Leetown (W. Va.) station to investigate an epidemic of blue sac which was causing heavy losses among the brook and brown trout fry. In contrast with other investigators, Dr. Fish was unable to find any definite evidence that the disease was due to a specific infection. Cultures of the serus fluid gave negative results except in a few instances. Sections of the diseased tissue also failed to disclose any evidence of bacterial activity and there was nothing to indicate that the disease spread from one trough to another as is usually the case with bacterial infections.

During the summer Dr. Fish was detailed to cooperate with the Oregon State Game Commission in a study of fish-cultural problems which had arisen in connection with the operation of the State trout hatcheries. Field headquarters were located at the Oregon State College, Corvallis, and inspection trips were made to all but two minor State trout hatcheries and to many points where the Oregon Game Commission had been carrying on field work. The purpose

of these trips was to review the entire system of trout propagation and management in the State. Special attention was paid to the prevalence and control of disease among hatchery fish. At the end of the season a report was prepared on the operation of the individual trout hatcheries based on actual observations and on a questionnaire sent to all hatchery superintendents.

In order to facilitate the study of diseases which are becoming a serious problem in many trout and salmon hatcheries in the West it was decided to install a pathological laboratory at the Fisheries biological station in Seattle with Dr. Fish in charge. The need for such a laboratory is very evident since there are reasons for believing that in addition to most of the diseases which affect trout at Eastern hatcheries there are other diseases which are peculiar to this region or at least have not yet been found at Eastern hatcheries.

Experiments have been conducted looking toward the improvement of methods of treating fish in pools by allowing a very dilute chemical solution to flow into the pool at a uniform rate. Solutions of potassium permanganate, copper sulphate, and chlorine have been recommended for this purpose, but in no instance have the methods yet devised proved entirely satisfactory. It has been found extremely difficult in practice to treat fish in pools with such solutions without serious danger of killing large numbers of fish. In some instances very satisfactory results have been obtained, but in other cases heavy losses have occurred when using the same treatment. It is believed, however, that these difficulties can be eliminated largely by further experiment in the technique of treatment.

An experiment to test the value of iodine as a cure for furunculosis was carried out at the Pittsford station. For this purpose a lot of yearling California golden trout, which are quite susceptible to the disease, was divided into two equal lots and placed in small circular pools. Before beginning the experiment these fish had been showing a small daily mortality from furunculosis for some time. One lot was used as a control, the other lot was placed on a diet containing salmon oil and a solution of iodine according to the recommendations of E. R. Hewitt. The experiment was started August 10 and for the first 13 days the losses in both lots were approximately the same. The total losses on August 23 were 46 in the lot given iodine and salmon oil, and 47 in the controls. The supply of salmon oil was exhausted on that date and the iodine solution soon after, but the experimental lot was kept on a dry diet supplied by Mr. Hewitt for a month longer. During this period the loss among this lot was appreciably less than among the controls. The experiment was discontinued on September 22 at which time the losses among the lot on the Hewitt diet totaled 74 and among the controls 144.

While these results show approximately twice the mortality among the controls as among the fish kept on the Hewitt diet, it is by no means demonstrated that this difference was due to the inclusion of iodine or salmon oil in the food. As a matter of fact, the supply of both of these constituents was exhausted at about the time the fish began to show improvement, and the decreased mortality among the experimental lot may easily have been due to other causes. In previous experiments marked differences in mortality from furuncu-

losis have been observed frequently among fish on different diets. Whatever the explanation, these experiments evidently lend little support to the view that iodine is a specific cure for furunculosis.

STREAM SURVEY AND STREAM IMPROVEMENT

During the summer of 1934 the Bureau inaugurated an extensive series of stream survey and improvement work in the national forests and parks in cooperation with the United States Forest Service and the United States Park Service. This work was made possible by an allotment of $127,500 from the Public Works Administration.

Stream surveys.—The stream surveys were conducted by 16 parties operating in forests and parks in various parts of the country. In most cases each party was composed of a biologist in charge, three assistant biologists, and a camp attendant. The equipment of each party consisted of a complete camping outfit, a 2½-ton pick-up truck, and the necessary apparatus for collecting physical, chemical, and geological data on lakes and streams. Because of climatic conditions, the time spent in the field varied greatly in different sections. One of the survey parties in the South, for instance, was in the field for over 8 months while those working at high altitudes in the West were in the field for only 3 months.

The primary purpose of the surveys is to provide an inventory of conditions in each lake and stream which affect the fish population. With this information at hand it will be possible to determine what species of fish is best adapted to each body of water and the number it can support most advantageously. This knowledge is essential for the development of a rational and systematic stocking policy which will make possible the most efficient utilization of forest waters. In the absence of such basic information, fish are frequently planted in waters to which they are not adapted, and in numbers which have no relation to the productive capacity of the stream.

In the East four parties surveyed completely or in part the Great Smoky Mountains National Park in North Carolina and Tennessee, and the following national forests: White Mountain and Green Mountain in New England, George Washington and Monongahela in Virginia and West Virginia, and Pisgah and Nantahala in North Carolina, South Carolina, and Georgia. The 12 parties operating in the Rocky Mountain region covered completely or in part the Glacier National Park and the following national forests: Wyoming, Challis, Sawtooth, Cache, Wasatch, Rapaho, Humboldt, Santa Fe, Carson, Coconino, Apache, Tonto, Crook, Mono, Inyo, Sequoia, Shasta, and Klamath.

A report including the important data collected by the survey parties and recommendations for stocking has been prepared for each forest. These reports give brief accounts of the physiography of the region followed by a description of the principal streams and lakes of each watershed, including the physical and chemical characteristics and accessibility. This is followed by a discussion of the biological characteristics of each body of water, including the fishes and other vertebrates, the kinds and relative abundance of food organisms, and the presence of aquatic plants. A summary

of the essential data required for developing a stocking program for each body of water is given in tabulated form, accompanied by stocking recommendations.

STREAM IMPROVEMENT IN CONNECTION WITH THE STREAM SURVEYS

Extensive work in stream improvement was carried on in the national forests in cooperation with the Forest Service. Except in a few instances, the work was done by C. C. C. labor under the supervision of men employed by the Bureau. Since there are few reliable data on which to base an estimate of the true value of stream improvement the work was primarily experimental.

It is evident that the nature of improvements which will prove of most value will vary widely with conditions and for that reason stream conditioning was carried on in as many different types of streams as possible. Very little work has been done heretofore on swift, mountain streams such as are found in the great majority of the national forests. Such streams are obviously more difficult to work with than sluggish, meadow streams which have been the type on which most improvement work has been done in the past. In some instances streams were selected for improvement that offered most serious obstacles to permanent installations for the purpose of subjecting the devices to the most rigorous tests. Preliminary reports indicate that most of these installations have withstood the effects of exceptionally heavy floods with little damage.

At the conclusion of the summer's work a memorandum was prepared on "Methods for the Improvements of Streams." This memorandum contains a discussion of the principles of stream improvement and detailed descriptions of the devices which have been found to be of greatest value.

INVESTIGATIONS IN THE ROCKY MOUNTAIN REGIONS IN THE INTEREST OF FISH STOCKING

The Bureau's investigations in this region by Dr. A. S. Hazzard are almost solely directed toward the betterment of sport fishing. Commercial fishing at present is restricted to the taking of whitefish in certain States and to limited sucker and carp fisheries in others. Angling (principally for trout) is becoming increasingly popular with the resident and tourist, while in the majority of areas the fishing is rapidly deteriorating. The rapid development of new roads and trails and the accompanying increase in angling have necessitated extensive stocking and environmental improvement.

Investigations during the past 4 years have demonstrated the need for intensive studies of the life histories of the principal native game and forage fish in order to determine their requirements. Such studies should indicate the types of waters to which they are best suited and how their environment can be improved. Similar studies of so-called "obnoxious" fishes such as the chub, bony-tail squawfish, and sculpin are also necessary in order to learn the extent of their competition with game fishes or their unsuspected value to these fishes. This information is necessary before intelligent efforts toward control can be made, if such control proves desirable.

Prior to 1934, the following investigations were undertaken: Survey of Grand Teton National Park, Wasatch Forest studies, initiation of Glacier National Park survey of food production in mountain streams and lakes, life history studies of the cutthroat trout and Rocky Mountain whitefish, also miscellaneous investigations in cooperation with various State fish and game departments.

During 1934, investigations in this region were expanded as a result of funds allotted from the Public Works Administration. Nine survey parties were assigned to the Intermountain States to study waters of certain national parks and forests. The following results were obtained:

The survey of Glacier Park was completed, thus furnishing the basis for a management plan which will maintain fishing in this popular recreation area. Valuable contributions to our knowledge of mountain lakes and streams will also be made as a result of this study. Papers by specialists concerning the physical and chemical conditions, aquatic plants, plankton, and fishes are in preparation for publication.

The survey party assigned to Idaho studied certain waters in the Salmon, Sawtooth, and Challis Forests. As a result of these studies detailed plans for stocking and otherwise improving the lakes and streams of this popular area have been furnished. The apparent failure of previous plantings of smelt and eastern landlocked salmon was demonstrated by this investigation. Also a planting in 1931 of pond weed seed (*P. pectinatus*) in Pettit and Stanley Lakes was shown to have failed. Numerous gill-net sets in Redfish, Pettit, Alturas, and Stanley Lakes indicated a great abundance of suckers and squawfish but no trout, other than a few native Dolly Varden. It is apparent, therefore, that the heavy plantings of various species made have failed to benefit the lakes. Studies of the life history of the squawfish and suckers should be made in order to effect their control.

In Utah a survey of the Cache Forest and certain waters of the Wasatch and Ashley Forests revealed the need for stream improvement and indicated that more intelligent planting would produce better fishing. Detailed plans for this work have been prepared based on data collected.

The survey party also cooperated with the Bureau of Animal Industry and the State fish and game department in determining the effects of the proposed copper-sulphate treatment in trout streams. A concentration of 1:500,000 was used for 24 hours in East Canyon Creek. The results indicated that wherever the concentration was strong enough to kill the objectionable snails it was deadly to trout, though not harmful to the other fish food.

In cooperation with the United States Forest Service, experiments in the fertilization of small, high mountain lakes were initiated. Since soil and water analyses of these lakes and a highly productive trout lake (Fish Lake) demonstrated a deficiency in carbonates, phosphates, and nitrates in the former, known quantities of these substances were introduced to determine the practicability of fertilization. Aquatic plants and fish food organisms from Fish Lake were also introduced. Detailed quantitative studies of chemistry and food

supply made prior to these alterations will be repeated later to determine the results.

The survey party in Nevada studied the streams and lakes in a portion of Humboldt Forest. Although difficult of access, these waters are becoming more heavily fished each year and stocking plans for them are in great demand. The superiority of eastern brook and cutthroat trout over the rainbow for these high waters was clearly proved by results of the survey. The need for pool improvement was also demonstrated.

In Arizona the survey party examined the waters of the Coconino, Tonto, Crook, Coranodo, Apache, and Tusan Forests, and a portion of the San Carlos Indian Reservation. The enormous area covered was due to the scarcity of water in this region and the numerous roads. However, this very scarcity enhances the value of the public fishing water and is resulting in strenuous efforts of the fish and game commission and Forest Service to maintain the angling. The need for more systematic stocking, better regulation, stream-improvement work, and erosion control was demonstrated by the survey.

Portions of the Santa Fe and Carson Forests were studied by the New Mexico party. These areas are used extensively for recreation and the fishing has been declining in spite of the excellent work of the fish and game commission. The survey's results indicated a need for stricter regulation of fishing or more frequent planting of legal-sized fish. Recommendations for additional stream and lake improvement were also made.

The Colorado survey party worked in close cooperation with the Forest Service in carrying out the program for improvement of fishing in the Arapaho, Roosevelt, Pike, and San Isabel Forests. Recommendations for stream improvement and rearing pond construction were acted upon immediately during the past season. Detailed plans are being prepared which should assist in the stocking of these waters.

The Wyoming survey party studied a portion of the Wyoming Forest. The lower waters in this area, which are accessible by road, are heavily fished. It is the desire of the fish and game commission and the Forest Service to stock the higher waters according to their requirements in order to induce the anglers to fish there, thereby relieving the strain on the lower waters. Because of transportation difficulties only a limited number of waters could be studied this season. However, sufficient information was secured to enable some generalizations covering the species best adapted, and the intensity of planting which should be carried on in this region.

COOPERATION WITH THE FOREST SERVICE IN STREAM AND LAKE IMPROVEMENT

The West Fork of Rock Creek in the Deer Lodge Forest in Montana was selected as an experimental stream-improvement project. Careful counts of the fish and fish-food population were made in a section of this stream. Sixty-eight structures of various types were then installed. An accurate, large-scale map showing bottom types, location of counts, plant beds, and structure location was made. Careful studies in the future will be carried out to determine the benefit of the improvement work in this stream.

In each of the other seven States of this region the Bureau detailed an investigator to assist the Forest Service in stream-improvement work. It was his duty to prepare plans for the streams designated by the Forest Service and to furnish technical supervision. These men worked in 30 national forests in the region and planned 5,604 improvements, of which approximately half were completed this season. This work was recommended for 153.8 miles of stream, or approximately 36 structures per mile. The major part of the construction was accomplished by the C. C. C., although some was financed out of other Forest Service funds.

In order to determine the effectiveness of various devices in different types of streams, each structure was tagged and notes were taken concerning conditions before and after installation. A check of the work following the spring run-off should indicate the most successful structures for the streams of this region.

In addition to stream improvement, a limited amount of lake alteration was planned by these workers. Raising the outlet to increase the area and installing brush covers to furnish shelter for fish were carried out as experiments in a few selected lakes.

COOPERATION WITH THE UNIVERSITY OF UTAH

A number of advanced students registered for special work under the Bureau's direction have been pursuing certain basic fishery investigations. Life-history studies of several species of fish are in progress. A comparative study of some Utah trout streams and studies of the rate of food recovery in streams affected by floods are also being made. The collection of fishes which is being built up at the University Museum will be of great value both for the instruction of students and for future studies in this region by the Bureau or other investigators.

The impetus given to the study of fishes and their environment should aid greatly in the solution of the many problems confronting the agencies concerned with maintaining the sport fishing in this region.

INVESTIGATIONS IS INTERIOR WATERS

The extensive activities of the unit under the direction of Dr. M. M. Ellis have been made possible not only by the cooperative work of the various members of the staff, but also because of the cooperation of the Corps of Engineers of the United States Army, the Tennessee Valley Authority, and Division of Fish Culture of the United States Bureau of Fisheries. Active work was maintained throughout the year at the Columbia (Mo.) laboratories and at the substation, Fort Worth, Tex., and for considerable portion of the year on the floating laboratory, U. S. Quarterboat *348* and at the Neosho (Mo.) hatchery.

During the past 12 months the activities have followed three major lines.

POLLUTION STUDIES (F. P. 41 PROJECT)

During the course of the pollution studies streams and other bodies of water have been examined in 21 States, and a detailed survey of the

Mississippi River with reference to the effects of pollutant effluents on that stream has been made from Cairo, Ill., to Grand Rapids, Minn. The Mississippi River was chosen as presenting typical problems of a major stream receiving a variety of pollution effluents. Studies on other streams in different States have been made with reference to specific pollution problems as well. The effluents from some 15 types of industries representing over 80 industrial plants have been studied both in the field and in the laboratory. In addition, mine wastes, particularly from coal, lead, copper, iron, zinc, and arsenic mines, have been analyzed and assayed as pollutants. Oil pollution of fresh water has been given detailed attention in the States of Kansas, Oklahoma, Texas, and Louisiana, particularly during the months of October to January, inclusive; and these findings correlated with oil pollution already noted in our field work elsewhere.

Municipal effluents and garbage pollutants were given specific attention in the St. Louis, Davenport, and Minneapolis-St. Paul areas. During November a field party made an extensive study of the best sugar industry effluents in Nebraska, Colorado, and Kansas, and other field parties have studied the sulphur pollution in Louisiana, limestone wastes in Indiana, natural alkali pollution in North Dakota and Montana. All of this pollution work has had as a major objective the determination of: (1) The effects of these substances on fish life, particularly the major types of fresh-water fishes; (2) the effects of these substances on fish food, specifically those insects, crustaceans, and mollusks, which constitute a large part of the food of fresh-water fishes; and on the aquatic bacterial flora, particularly those forms concerned with the utilization of organic wastes and those forms which are part of the food chain series in fresh waters; and (3) the chemical and physical balances of the various substances occurring naturally in many of the fresh-water streams of the United States.

From these studies standards of water purity have been determined for fish life and measurements of pollution hazards made which can be applied quite generally to the fresh-water streams of the United States. New and practical methods for measurement of pollution hazards, relative toxicity, and importance of pollution effluents have been perfected in the course of this work. The work completed shows definitely the size of the task involved and the needs for continuation of studies along these lines.

POWER DAM LAKES AND OTHER IMPOUNDED WATERS

Studies of power dam lakes and other impounded waters have been carried forward, particularly in connection with the Tennessee Valley Authority projects in the Norris Dam area and in connection with the Fort Peck Dam which is being constructed in Montana. As a result of these studies, recommendations have been made to the Tennessee Valley Authority, and certain special lateral lakes are now being established in the Norris Dam area to insure the maintenance of fish food and young fish supplies in these areas.

The Fort Peck area was given a general survey and preparations made for the continuation of this work this spring, when the construction will have proceeded further.

In conjunction with the Corps of Engineers, United States Army, survey work, analyses, and experimental tests were made back of several of the new dams which have been constructed as part of the Mississippi River channel project and recommendations made concerning the effect of these constructions on water conditions, fish food, and other fisheries interests in the impounded waters held by these dams.

MUSSEL PROPAGATION

The mussel propagation experiments which were started at Fort Worth 2 years ago have been continued throughout the past year, and detailed data collected concerning the growth, mortality, and resistance of fresh-water mussels which are being grown under controlled conditions in close quarters in the experimental raceways at the Forth Worth project. The results of these experiments continue to to be favorable to this method of artificial propagation, especially for certain species. As a corollary of the work at Fort Worth, a new shipping container has been devised, making it possible to ship live mussels long distances with very little loss.

INDEPENDENT ACTIVITIES OF THE FISHERIES BIOLOGICAL LABORATORIES

WOODS HOLE, MASS.

Lack of sufficient funds for the operation of the Woods Hole laboratory prevented the Bureau of Fisheries from providing the customary facilities for independent investigations at this laboratory.

Robert A. Nesbit, assisted by William C. Neville, ran parallel series of tests of methods of marking scup by insertion of tags into the coelomic cavity, in which it was found that the most successful method consisted of inserting flat celluloid strips $1\frac{1}{8}$ by $\frac{5}{16}$ inches. With this method 8 percent of the tags were lost during the first 3 weeks, and none was lost during the following 12 weeks of observation. By developing a marking technique in which losses are small and definitely ascertained, it becomes possible not only to trace the migrations of this species but also to determine what portion of the mortality is due to commercial fishing and what portion is due to natural causes, two items that are fundamental in formulating a conservative policy.

BEAUFORT LABORATORY

The Beaufort (N. C.) laboratory was severely damaged to the extent of over $10,000 by the tropical hurricane of September 16, 1933. It was possible, however, with funds provided by the Public Works Administration, to restore the buildings and equipment by the following spring and continue operations for the propagation of the diamondback terrapin, and investigations concerning oil pollution and serious natural enemies of oysters in the South Atlantic and Gulf region. With additional funds provided by the Public Works Administration, a bridge has been constructed to connect the laboratory with the mainland, which will increase the protection of the Bureau's property in case of fire and tropical storms and will enable the gen-

eral public to inspect the station's exhibits of marine animals, fishing equipment, and methods developed for increasing the propagation of oysters and the diamondback terrapin.

Research.—Operation of the Beaufort laboratory was continued throughout the year under the direction of Dr. H. F. Prytherch and furnished facilities for the study of fishery problems of the South Atlantic and Gulf region. The chief investigations conducted here by the Bureau's staff, as reported in detail elsewhere, consist of (1) physiological effects of Louisiana crude petroleum and oil-well brines on the oyster; (2) studies of a protozoan parasite of the oyster associated with mortalities in Louisiana and Virginia; and (3) cytological studies of the ova and germ-cell cycle in two species of shrimp. The laboratory serves as headquarters for oyster investigations in the South Atlantic and Gulf States and, in cooperation with the conservation departments of North Carolina, South Carolina, and Florida, directs extensive operations for the rehabilitation of public oyster beds with funds provided by the Federal Emergency Relief Administration. Field investigations have also been made of the serious destruction of oysters in Apalachicola Bay, Fla., by a flatworm parasite, *Stylochus inimicus*, commonly known as the "wafer" or "leech."

Laboratory facilities for marine research have been furnished to 27 investigators from other institutions who were engaged in the following studies: Dr. H. V. Wilson, University of North Carolina, the biology of sponge cells, with particular reference to the fine cytoplasmic reticula formed in metamorphosing larvae and regenerative masses; Irene Bolick, University of North Carolina, dissociation and reunition of sponge cells of several local species; Dr. A. S. Pearse, Duke University, assisted by H. W. Hatsel and E. D. Huntley, ecological studies of estuarine animals; Dr. Bert Cunningham, Duke University, effect of temperature on embryonic development of the diamondback terrapin; Dr. Paul L. Risley, State University of Iowa, transplantation of reproductive organs and sex differentiation in the terrapin; Dr. George G. Scott, City College of New York, comparative histology of marine fishes; Dr. and Mrs. B. G. Chitwood, United States Department of Agriculture, identification and distribution of free living marine nematodes; Dr. W. C. George, University of North Carolina, studies of chordate blood and regeneration in the ascidian Styela; Dr. Hoyt S. Hopkins, New York University, respiration in marine mollusks in relation to oxygen tension; Dr. W. E. Bullington, Randolph Macon College, studies of marine ciliates; Dr. Lowell E. Noland, University of Wisconsin, morphology and taxonomy of ciliate protozoa, particularly those of the order Peritricha; L. Lyndon Williams, Rensselaer Polytechnic Institute, tissue regeneration in hydroids and related forms; Reinard Harkema, Duke University, parasites of rodents occurring on the coast of North Carolina; Dr. Hugh H. Darby, Bartol Research Foundation, regeneration of chelipeds in Alpheus and Uca; G. Robert Lunz, Jr., Charleston Museum, Stomatopoda of the Beaufort region; Dr. J. Paul Visscher, Western Reserve University, rare species of barnacles.

In cooperation with the Federal Emergency Relief Administration, laboratory facilities were provided for the employment of eight college-trained women on a research project covering studies of the com-

plete life cycle of the black skimmer, *Rhynchops nigra*. The project was carried out under the supervision of Dr. Alice L. Brown, with the assistance of M. Waynick, A. L. Bason, A. S. Sherrill, B. Arnold, and L. Jarrett, of the North Carolina College for Women; I. Bolick, University of North Carolina; and R. L. Collie, of the North Carolina State Museum. Particular attention was given to the development of the embryo, growth, and morphology of the mandibles and the differentiation of sex. Material for these studies was obtained from the rookeries of the black skimmer on the Georgia coast and from several located in Pamlico Sound, N. C.

The facilities of the station were also utilized by the United States Chemical Warfare Service for tests of wood preservatives, and by the Bureau's Division of Fishery Industries for experiments on the durability of net twines treated with different preservatives. Cooperative tests were continued with the Woolsey Paint Co. in respect to the antifouling value of copper paints, and with the Tropical Paint & Oil Co. on the suitability of bakelite varnishes for marine use.

Terrapin culture.—Operations for the propagation of the diamondback terrapin, conducted in cooperation with the Division of Fish Culture, were unusually successful during the summer of 1934, when a record hatch of 12,446 young was obtained. In addition to this number approximately 1,000 eggs, embryos, and young terrapin were supplied to investigators from Duke University and the State University of Iowa for studies of development and possible control of sex in this species. During the spring of this year 10,445 young terrapin from the 1933 brood were distributed in southern coastal waters in cooperation with the North Carolina Department of Conservation, the South Carolina State Board of Fisheries, and the Georgia Department of Fish and Game.

The system of propagation has recently been modified and improved by simulating natural conditions, so as to permit hibernation of the young terrapin during the winter months in protected outdoor pens. This arrangement has not only reduced the cost and labor of their care in a heated rearing house, as required previously, but has considerably increased the number surviving the critical 9-month period from hatching to liberation. It was first tried with the 1933 brood, of which over 98 percent were grown to a suitable size for distribution. Though record low temperatures occurred during the hibernation period, the total losses of young terrapin in this brood amounted to only 179, as compared with losses ranging from 700 to over 3,000 during previous years.

The annual production of young diamondback terrapin at the Beaufort station hatchery since 1930 has been as follows: 1930, 5,778; 1931, 5,500; 1932, 11,086; 1933, 10,060; 1934, 10,445. These operations have been successful from a practical standpoint since 1912 and have provided over 70,000 terrapin for breeding purposes and restocking of coastal areas. Since the consumption and market demand for terrapin has increased considerably in the last 2 years, it is advisable that artificial propagation of this species be continued and expanded, and an effort made to develop State hatcheries for this purpose.

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